Small Transport Aircraft Technology

AN INTERIM REPORT FOR THE
COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

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EXECUTIVE SUMMARY

Introduction

On May 10,1978, the U.S. Senate Committee on Commerce, Science, and Transportation stated that they perceived a problem in air service between smaller cities and major hubs, or commuter-type small community air transportation. They requested that NASA, in consultation with the Department of Transportation and the Civil Aeronautics Board, prepare a report on (1) technical improvements in commuter aircraft that would likely increase their public acceptance and use, and (2) whether NASA's aeronautical research and development program could help commuter aircraft manufacturers solve these technical problems.

In response to this request, NASA established a "Small Transport Aircraft Technology" (STAT) research team at the Ames Research Center to provide for the planning, coordination and implementation of appropriate studies, analyses, and research. Close contact was maintained with the DOT, FAA and CAB in the preparation of this report. NASA also visited many potential U.S. commuter aircraft manufacturers, commuter and local-service airlines, and other interested organizations. Based on these discussions, the important technology dependent factors affecting public acceptance and use of small transport aircraft have been identified (Figure i). This interim report presents a preliminary assessment of the research and technology that NASA could undertake to improve small transport aircraft and outlines the advanced technologies currently under study for potential application to the small transport aircraft of the future. The report includes background information on the commuter and short-haul local service air carriers, the regulations pertaining to their aircraft and operations, and the overall airline system interface.

Background

With the introduction of the Douglas DC-3 into scheduled airline passenger service in 1936, the trunk airlines grew rapidly and as they obtained larger aircraft they began to reduce service to the smaller communities. In July 1944, the CAB instituted a "local service airline" program to continue air service to the smaller communities. The new local service airlines formed as a result began operation with DC-3s and as they grew, following the pattern of the trunk airlines, began expanding and upgrading their fleet with the addition of larger equipment. They progressed to larger piston engine aircraft, then to still larger turboprop aircraft, and currently the majority are retiring their remaining older turboprop aircraft for 80-120 passenger turbofan aircraft. These larger, turbofan aircraft are inefficient for short-haul, low-density air service and a number of the smaller communities are again faced with a loss of air service.

In order to maintain air service to small communities, a new category of scheduled air carriers emerged and were classified as Commuter Air Carriers by the CAB in 1969. Since then the public need for the commuter airlines has increased and service has grown to 10.1 million passengers and 401.6 million pounds of cargo carried in 1978. The growth of commuter air service has been encouraged by recent regulatory changes. The "Airline Deregulation Act of 1978" permits operation by commuter air carriers of aircraft up to 55 passengers or 18,000 lb. maximum payload capacity. The CAB recently finalized a rule extending the aircraft size to 60 seats. To meet the future needs of commuter airlines the FAA has instituted a revised FAR Part 135 operations regulation and has drafted a new FAR Part 24 certification regulation for light transport category, multi-engine aircraft. Commuter airline passenger enplanements are forecast by the FAA to reach 16.5 million by 1990.

The current generation of U.S. produced aircraft in commuter airline use are principally derivatives of general aviation aircraft and were not designed to withstand the high utilization demanded by commuter transport operations. The Swearingen Metro is the only current technology, 19 passenger transport aircraft presently produced in the United States. All other current technology short-haul transport aircraft in the 19 passenger and greater capacity available to commuter airlines are of foreign design and manufacture (Figure ii). Recent forecasts for new light transport aircraft requirements from 1980 to the year 2000 project a world market for 800-3750 aircraft with a capacity of 15-19 passengers, 1147-3000 aircraft with a capacity of 20-39 passengers, and 1026-1500 aircraft with a capacity of 40-60 passengers. To insure good small community air service, a "family" of transport quality aircraft spanning the 15-60 passenger capacity range and designed specifically to the requirements of the expanding commuter airlines is needed both in the United States and abroad.

Technical Improvements

Technology is only one of several factors influencing the evolution of adequate commuter service and the growth of a viable commuter aircraft industry. It is a key factor, however, in that it directly affects equipment first cost, operating cost, safety, comfort, fuel economy, and other primary considerations. In order to determine the technology advances most likely to provide desired improvements, and the research effort required to generate these advances, NASA has initiated a series of studies in which airframe, engine, and propeller manufacturers are evaluating the application of new technology to the design of improved, more efficient, small, short-haul transport aircraft. Precursor research has also been initiated within the NASA research and technology base programs to establish a data foundation and to explore some of the more obvious promising areas of improvement in the critical technical disciplines.

Examples of the advanced technologies which are being considered (Figure iii) and which might characterize the programs to be defined as the result of the initial studies, include the following:

Aerodynamics Technology - The performance and economics of small, short-haul, transport aircraft is strongly dominated by the aircraft climb capability and efficiency. Exploratory aerodynamics research has been initiated to assess the potential of improvements in airfoil, wing, high-lift device, and turboprop nacelle/wing designs and installations. Detailed aerodynamic analyses, selected small- and large-scale wind tunnel experiments, and selected flight tests could be conducted to develop an advanced aerodynamics technology data base.

Propulsion System Technology - Advanced turboprop and turbofan engine design studies have been initiated with several engine and propeller manufacturers. These studies are concentrating on the unique design characteristics of small transport sized (1000-5000 horsepower), severe duty cycle (high utilization), turbine engines. These include the increased sealing and cooling problems of small turbine blades, centrifugal compressor design, and the increased sensitivity to in-flight engine shut-down for twin engine aircraft. The result of advanced propulsion research could be improved design capability which could be verified through ground testing of selected engine components. Propeller technology studies have also been initiated to examine the application of advanced technology to improve small transport propeller aerodynamic efficiency and reduce noise, weight, and maintenance. Improved design capability for advanced technology propellers could be verified through small- and full-scale wind tunnel testing of the most promising designs.

Aircraft Systems Technology - Small transport aircraft operate at lower altitudes and with lower wing loadings than large transport aircraft. As a result, the passenger ride quality is not as smooth and passenger comfort and anxiety are adversely affected. The potential for gust load alleviation systems technology to significantly improve the small transport aircraft ride quality, reduce pilot workload, and reduce wing structural fatigue is under consideration. Other systems research could include advanced flight control systems, avionics, and improved icing protection systems that could improve safety of flight, terminal area compatibility, and handling qualities. Included could be evaluations of the potential utilization of such advanced flight control system technologies as fly-by-wire or fibre optics for control signal transmission, electrically powered control actuators, and integrated electric-hydraulic actuator units. Avionics technology research could build on ongoing in-house avionics research in the areas of short-field, terminal area, guidance and navigation. Icing protection research could include development of analytical methodology for predicting icing phenomenon, conceptual design studies of advanced icing protection systems, and icing tunnel and flight test evaluations of advanced designs.

Structures Technology - A significant factor often adversely affecting the purchase and introduction into service of new small, short-haul transport aircraft is the high acquisition cost. A recent study indicated that the application of advanced structures, material, and manufacturing technology offers realistic potential for reducing the number of parts and the resulting acquisition cost of these aircraft. Flight type primary and secondary structural components incorporating advanced structures, material, and fabrication technology could be designed, built, and aerodynamically and structurally tested. Ground-based structural and materials testing of large components could include demonstration and evaluation of corrosion resistance, strength, and fatigue properties and characteristics aimed at the development of certification criteria.

Interim Conclusions

Recently, many social, economic, and regulatory changes have occurred which, coupled with increased passenger need for commuter air travel, have resulted in a strong demand for new, improved commuter aircraft and have significantly improved the opportunities for the application of advanced technology to the design of these aircraft. Small transport aircraft offer challenges because of the unique operational requirements resulting from their small passenger capacity, high frequency of daily operations over short stage lengths in a low altitude environment, and necessity to operate from small community airports as well as from the major hub airports. Based on discussions with aircraft manufacturers, airlines, and others, it appears that a need exists to clearly establish what an advanced technology data base could do for the design of improved, small, short-haul transport aircraft specifically focused on the operational needs of the commuter airlines.

In response to this need, NASA has initiated a broad range of advanced technology application studies with airframe, engine, and propeller manufacturers. These studies will assist in establishing the unique technology requirements for small transport aircraft, focusing the research into the most critical areas, and defining the research and development required to elevate appropriate advanced technologies to the point that they could be applied to new small transport aircraft with confidence. In its planning, NASA is taking into consideration the fact that many of the potential technology needs for future small, short-haul transport aircraft may not be unique and may be satisfied by applying the results from other ongoing or planned programs. In this interim report, research opportunities are outlined in all the technical disciplines for potential long-term application. However, results of the recently initiated technology application studies are required to establish the unique research required in the most critical areas. For nearer-term potential applications, it appears that technology advancements in aerodynamics, propellers, and gust load alleviation could be made. Research opportunities in these three areas are being explored at the present time. The results of these explorations and the broad technology application studies will be covered in the final report.

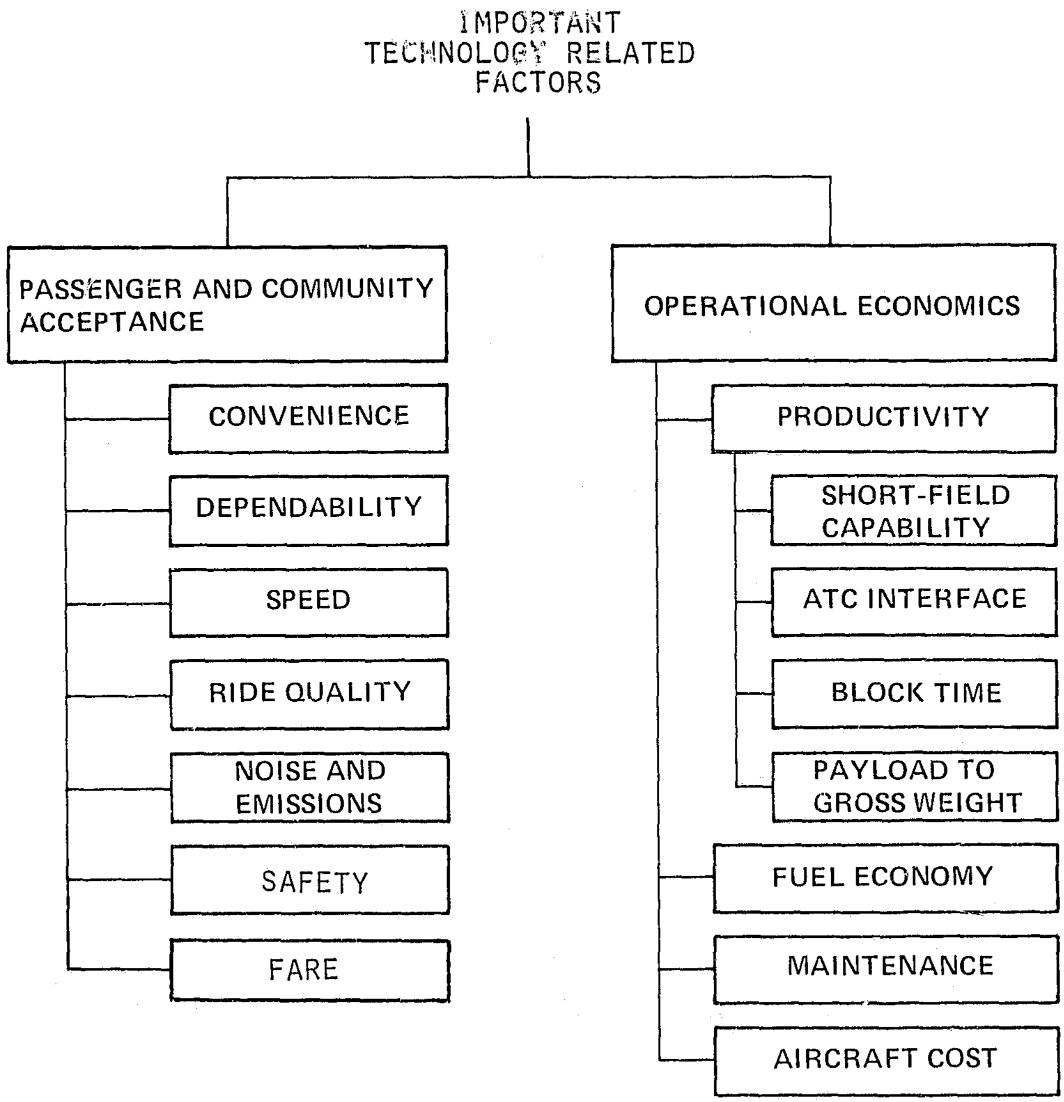

FIGURE i - IMPORTANT SMALL TRANSPORT AIRCRAFT TECHNOLOGY RELATED FACTORS

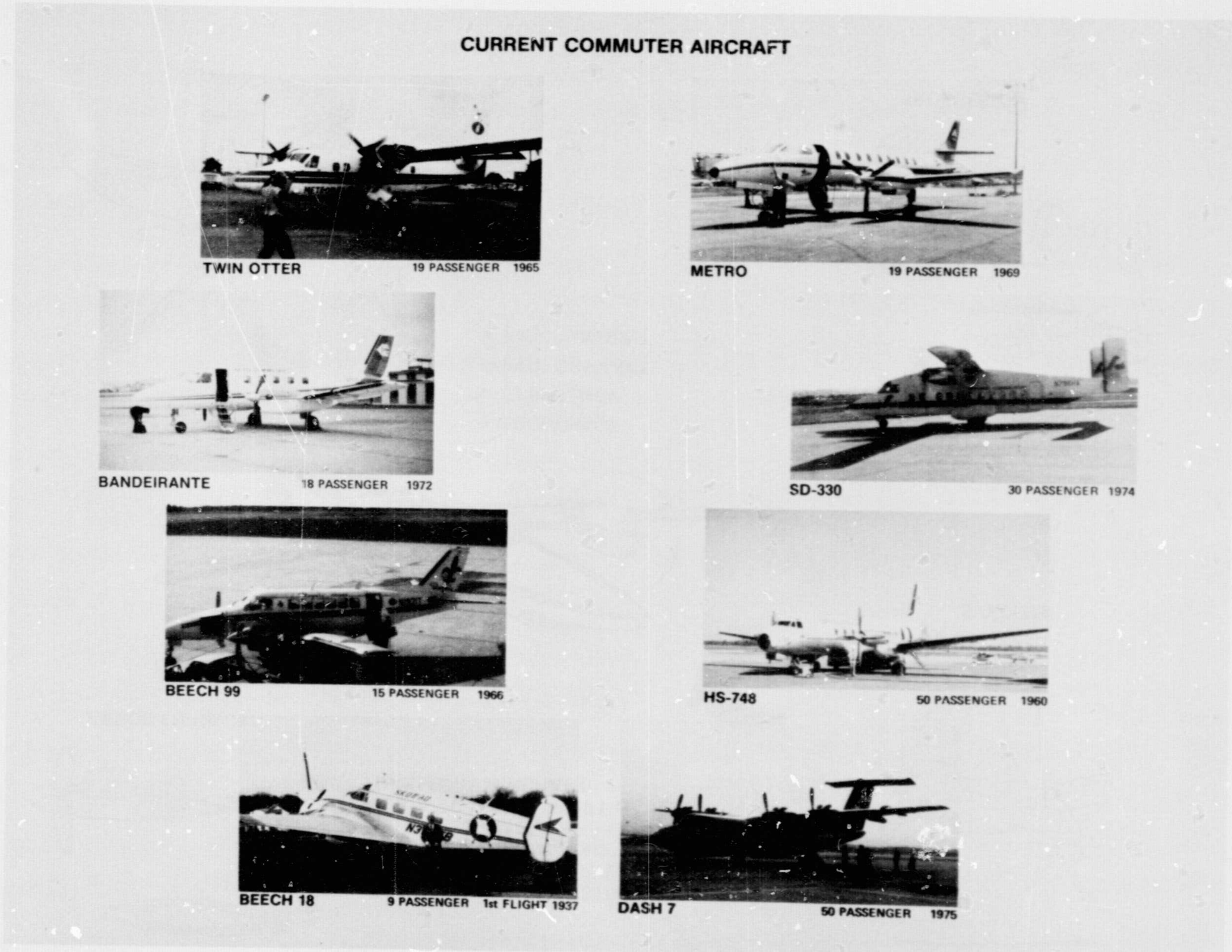

FIGURE ii - REPRESENTATIVE CURRENT COMMUTER AIRCRAFT

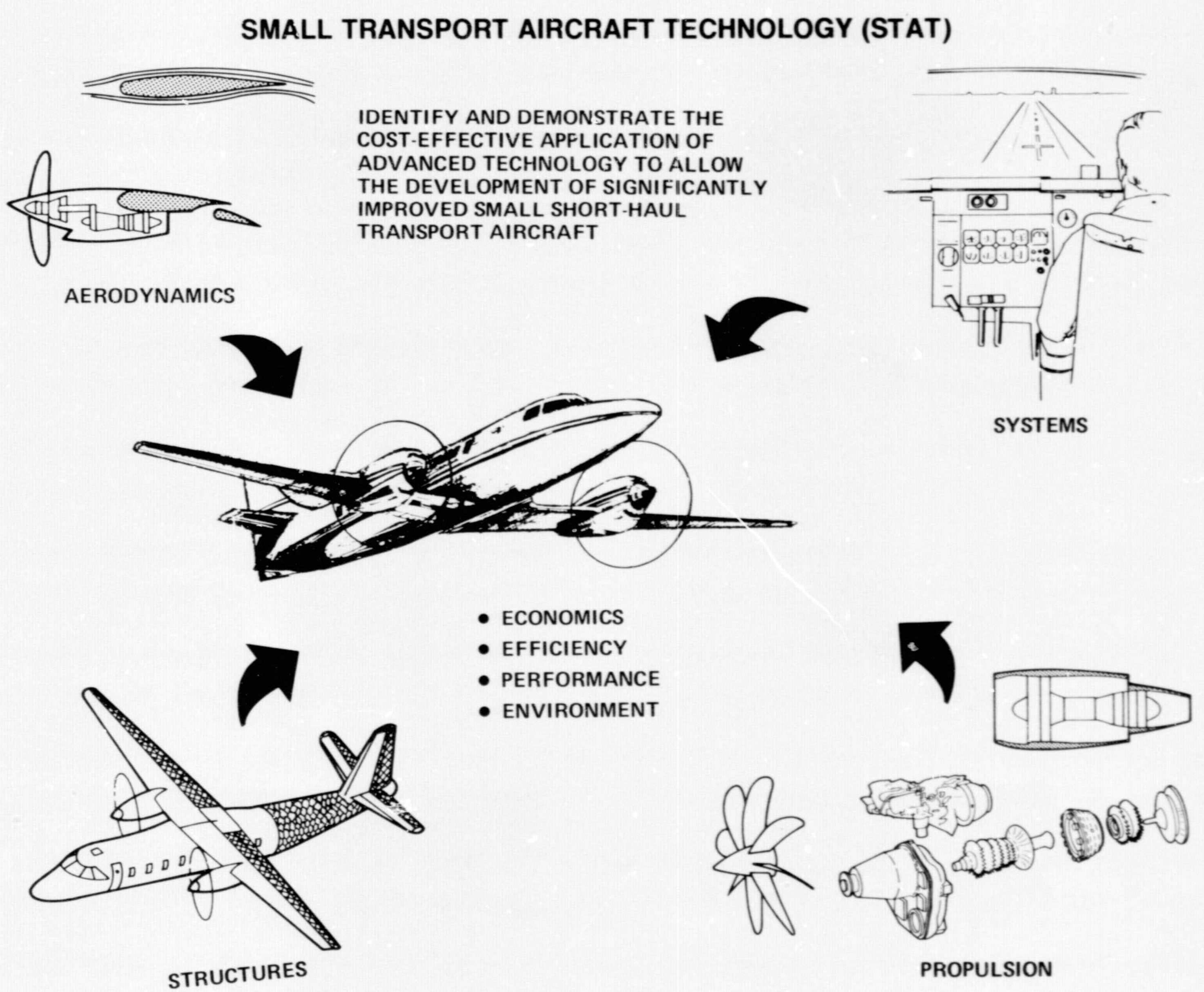

FIGURE iii - SMALL TRANSPORT AIRCRAFT TECHNOLOGY (STAT)

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INTRODUCTION

On May 10, 1978, in their report on the NASA Authorization for Fiscal Year 1979, the U.S. Senate Committee on Commerce, Science, and Transportation stated that they perceived a problem in air service between smaller cities and major hubs, or commuter-type small community air transportation. The Committee stated that it was clear that one factor inhibiting public acceptance and use of commuter air transportation was the technological lag between commuter aircraft and the equipment used by the major civil air carriers. In an effort to address this problem area, the Committee requested that NASA, in consultation with the Department of Transportation and the Civil Aeronautics Board, prepare a comprehensive report on (1) technical improvements in commuter aircraft that would likely increase their public acceptance and use, and (2) whether NASA's aeronautical research and development program could help commuter aircraft manufacturers solve these technical problems.

This report is an interim response to the Committee's request. NASA has established a "Small Transport Aircraft Technology" (STAT) research team at the Ames Research Center to provide for the planning, coordination, and implementation of appropriate studies, analyses, and research, and has been in close contact with the Department of Transportation, Federal Aviation Administration, and Civil Aeronautics Board in the preparation of this interim report. (STAT personnel representing NASA, the DOT, FAA, and CAB representatives are listed in the Appendix).

Of primary importance in the final report will be the technology section which will address the concerns of the Senate Committee, and will contain the results of advanced technology application studies which have been initiated with several airframe, engine, and propeller manufacturers to define the technology needs for a new generation of significantly improved commuter aircraft. The technology section of this interim report presents a preliminary assessment of the research and technology that NASA could undertake to improve small transport aircraft and outlines the advanced technologies currently under study for potential application to the future design of improved, more efficient, commuter transport aircraft. To provide a basis for discussing the technology needs, the interim report includes background information on the commuter and short-haul local service air carriers; the regulation pertaining to the aircraft and operations by these carriers; and the commuter airline system interface with airports, air traffic control, and other air carriers.

BACKGROUND

Regularly scheduled airline passenger service in the United States began on March 1, 1925 when Ryan Airlines initiated the first regularly scheduled, year-round passenger service between Los Angeles and San Diego, California, a 120 mile trip, with a converted World War I single-engine Standard biplane in one and a half hours and carrying four passengers (Reference 1). Scheduled passenger service began to improve with the introduction of the Ford Tri-Motor airliner into U.S. commercial air service on December 14, 1926. This 3-engine, all-metal, fully-enclosed, high-wing monoplane led the way to substantially improved passenger service. The growth in passenger service from the Ford Tri-Motor era and the introduction dates of some of the more significant transport aircraft is illustrated in Figure 1. One of the most sucessful transport airplanes of all time, the Douglas DC-3, was put into airline service with American Airlines on June 25, 1936 between New York and Chicago. By 1938, DC-3's were carrying 95% of all U.S. commercial air traffic. It was the availability of many thousands of surplus WWII DC-3's....10,926 produced through May 1946 including the military versions C-47, C-53, R4D, and Dakota (Reference 2)... plus the availability of large numbers of military trained pilots and mechanics which spurred the rapid growth of commercial air transportation as we know it today. Recognizing this potential growth, Congress enacted the Civil Aeronautics Act of 1938 to create a single, independent agency...the Civil Aeronautics Authority..to regulate civil aviation. Under this Act, all airlines which had been operating continuously since May 14, 1938 were grant permanent Certificates of Public Convenience and Necessity. These airlines formed the cadre of trunk airlines that provided scheduled air service in the U.S. As the trunk airlines grew and obtained larger aircraft they began to reduce service to the smaller communities. In July 1944, the Civil Aeronautics Board instituted an "experimental" program (Reference 2) designed to provide better air service to the smaller, more isolated communities than could be provided by the growing trunk airlines. The new airlines, called "local service" airlines, were made eligible for federal subsidy for providing improved short-haul service to these low density markets.

LOCAL SERVICE AIRLINES

The local service airlines began operation in 1945 with Douglas DC-3's and have grown substantially since that time, carrying almost 48 million revenue passengers annually as of September 1978 (Reference 3). As they grew, the local service airlines, following the pattern of the trunk airlines, began expanding and upgrading their fleet with the addition of larger equipment. From the DC-3's they progressed to 40-50 passenger, piston engine powered Convair 240/340/440 and Martin 202/404 aircraft, 50-60 passenger turboprop powered Convair 580/600, Fokker F-27, and Fairchild FH-227 aircraft, and recently to 80-120 passenger turbojet and turbofan powered aircraft.

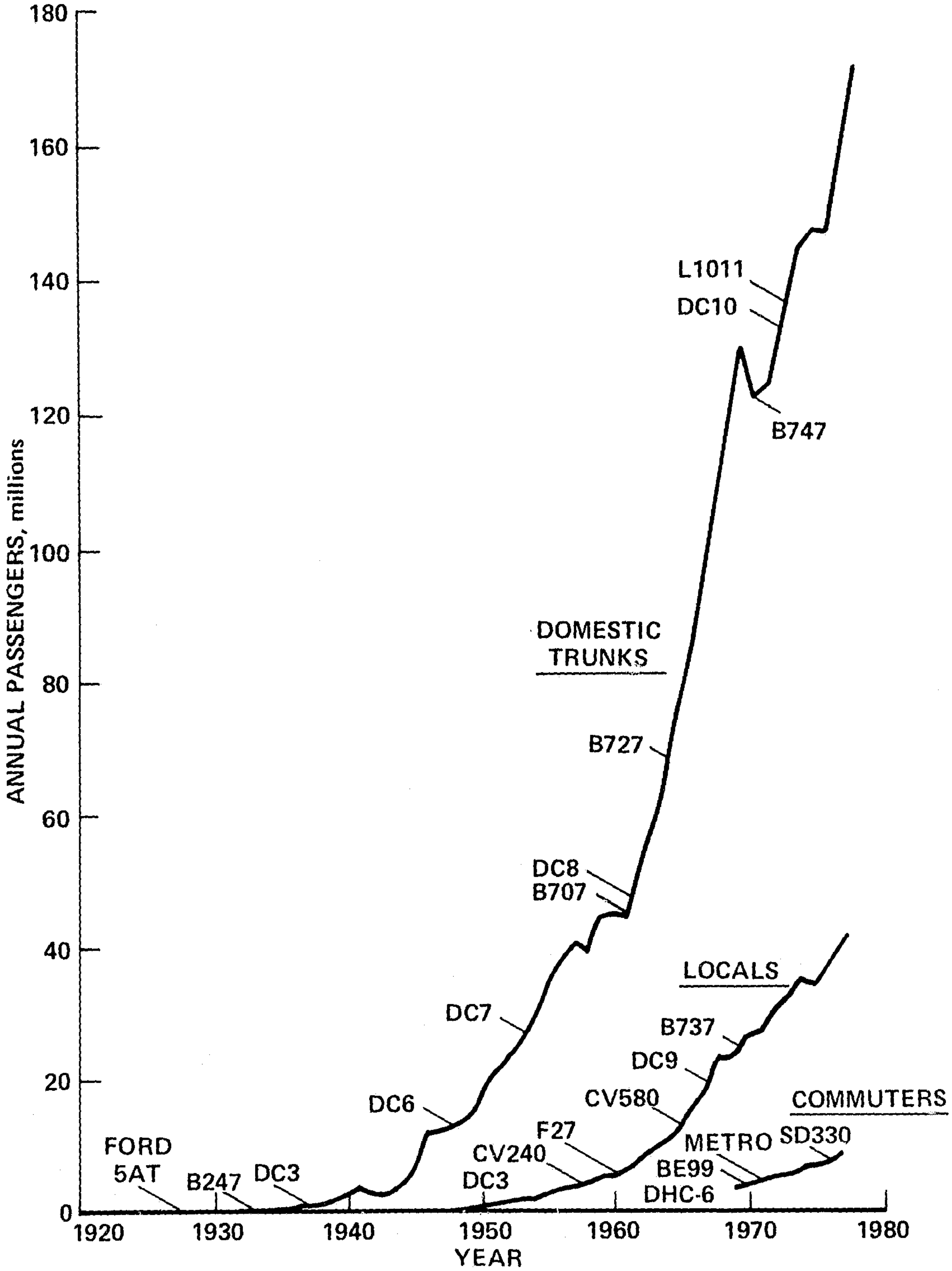

FIGURE 1. - HISTORY OF U.S. COMMERCIAL AIR TRANSPORTATION

The local service airline transition to a jet powered fleet is shown in Figure 2. Currently, most of the aircraft operated by the local service airlines are jet powered and have passenger capacities above 60 passengers. (Table 1). The majority of local service carriers have expressed a desire to retire their remaining older turboprop aircraft for the more productive, larger capacity jet aircraft. Since these larger, jet powered aircraft are inefficient for short-haul, low-density, small community air service, a number of the smaller communities which cannot be economically served with large jet aircraft...even with subsidy....are again faced with a loss of air service, this time by the local service airlines. Considering the easier market exit provisions specified in the Airline Deregulation Act of 1978, continued essential service to the small communities is a real national concern.

COMMUTER AIRLINES

In order to maintain necessary air service to communities which were too small for the larger aircraft being employed by the local service airlines, a new category of third level scheduled air carriers emerged, called "scheduled air taxis". Since their separate classification as Commuter Air Carriers by the CAB in 1969, public acceptance of the commuter airlines has increased and commuter airline service has grown from 4.3 million passengers and 43.5 million pounds of cargo carried in 1970 to 10.1 million passengers and 401.6 million pounds of cargo carried in 1978 (Reference 4 and Figure 3), when they served 819 airports representing 1676 passenger markets. Commuter airline passenger enplanements are conservatively forecast by the FAA to reach 16.5 million by 1990 (Reference 5). A further illustration of the commuter airline growth is shown in Table 2 from Reference 6 which compares the annual revenue passenger miles flown from 1971 through June 1978 by the domestic trunks, the local service carriers, and the commuter air carriers. The commuters annual percentage growth rate has, for the most part, been significantly greater than that of the domestic trunk and local service airlines. It is interesting to note (Figure 1) that the relationship between the commuter and the local service airlines, in terms of number of passengers carried, closely parallels the relationship existing between the local service and the trunk airlines 15 years ago. A further stimulant to growth of the commuter airlines occurred in July 1972 when the capacity restriction previously existing under the 1969 CAB classification as Commuter Air Carriers that limited them to the operation of aircraft less than 12,500 lbs. gross weight was changed to permit operation of larger aircraft of up to 30 passengers or 7500 pounds of payload.

Service Characteristics

Due to the diverse nature of the nation's small communities service needs, commuter air carrier market characteristics, route structures, and service patterns vary considerably across the country (Reference 7). Markets that have a potential for successfully supporting commuter air service range from

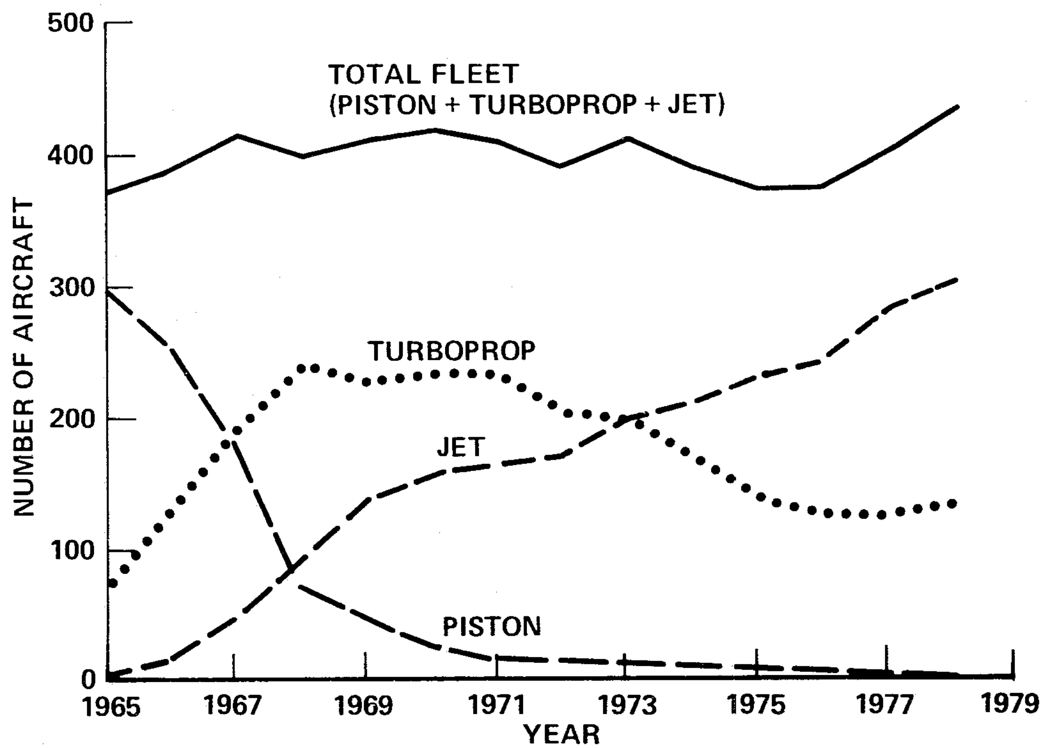

FIGURE 2. - LOCAL SERVICE AIRLINES
AIRCRAFT FLEET MIX

AIRLINE	60 PASSENGERS OR LESS		ABOVE 60 PASSENGERS	
	ALL TURBOPROP POWERED		ALL TURBOFAN POWERED	
ALLEGHENY	MOHAWK 298	9	BAC-III DC-9 B-727	30 48 5
FRONTIER	CV580 DHC-6	27 3	B-737	29
HUGHES AIRWEST	F-27	4	DC-9 B-727	39 4
NORTH CENTRAL	CV-580	23	DC-9	34
OZARK	FH-227	13	DC-9	32
PIEDMONT	YS-11A	18	B-737 B-727	20 5
SOUTHERN	SA-226 METRO	8	DC-9	30
TEXAS INTERNATIONAL	CV-600	3	DC-9	26
AIR MIDWEST	SA-226 METRO	5	—	0
AIR NEW ENGLAND	FH-227 DHC-6	7 10	—	0
ASPEN AIRWAYS	CV-580	10	—	0
WRIGHT AIR LINES	CV-600	6	—	0
	TOTAL (33% OF FLEET)	146	TOTAL (67% OF FLEET)	302

TABLE 1. - AIRCRAFT OPERATED BY LOCAL SERVICE AIRLINES (CONTINENTAL U.S. AS OF SEPTEMBER 1978)

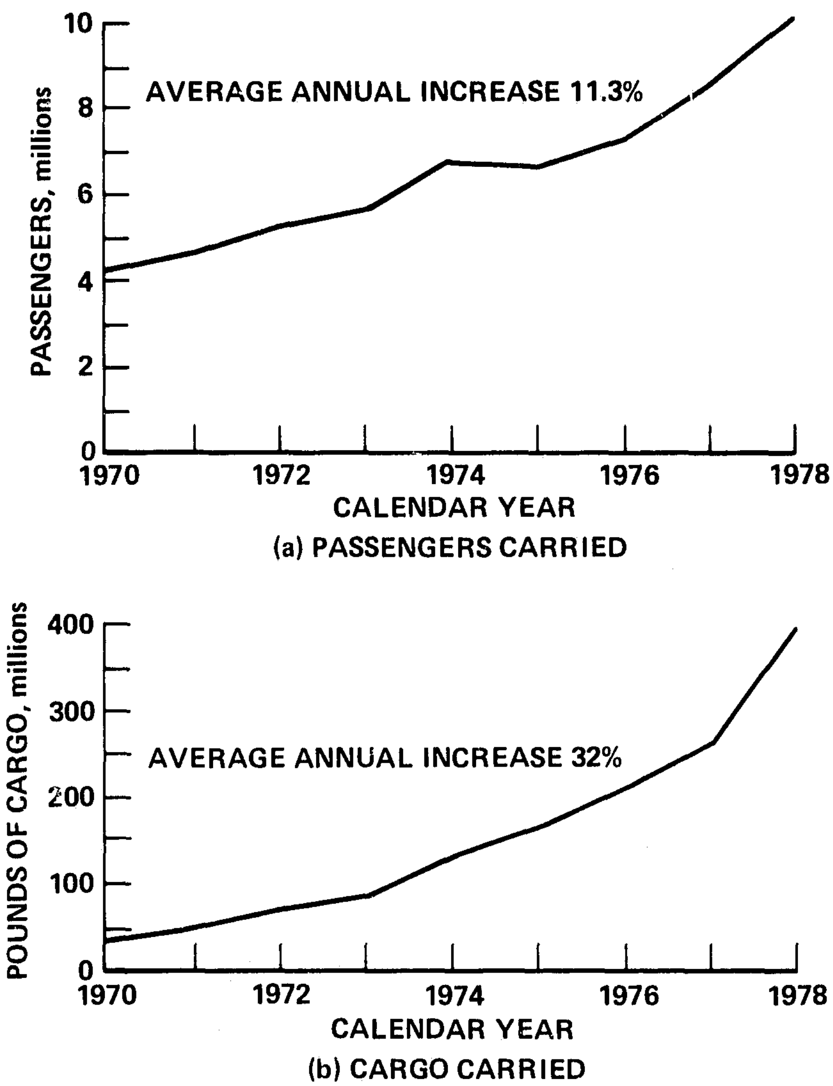

FIGURE 3. - COMMUTER AIR CARRIER ACTIVITY - SCHEDULED SERVICE DECEMBER 1970 TO DECEMBER 1978

YEAR ENDED JUNE 30	REVENUE PASSENGER MILES, millions					
				ANNUAL GROWTH RATE, %		
	DOMESTIC TRUNKS	LOCAL SERVICE	COM-* MUTERS	DOMESTIC TRUNKS	LOCAL SERVICE	COM- MUTERS
1971	95,786.3	7,593.7	442.0	—	—	—
1972	103,118.0	8,224.6	497.1	7.7	8.3	12.5
1973	112,018.6	9,438.8	549.1	8.6	14.8	10.5
1974	118,186.6	10,573.0	643.5	5.5	12.0	17.2
1975	115,917.4	10,365.2	708.0	-2.2	-2.0	10.0
1976	126,445.3	11,641.4	732.7	9.1	12.3	3.5
1977	134,642.1	12,675.9	834.2	6.5	8.9	13.9
1978	151,598.5	14,850.6	1,024.0	12.6	17.2	22.8

*INCLUDES CARIBBEAN AND ALASKAN COMMUTER CARRIERS

TABLE 2. - AIR TRANSPORTATION REVENUE PASSENGER MILES - U.S. DOMESTIC SERVICE

very short-haul markets serving interlining passengers to longer distance, linear route structures oriented toward collecting passengers to permit the conduct of a day's business in a major population center and a return on the same day. Special recreational markets also exist to provide air service from major population centers to resort areas. In general, however, there are certain common characteristics that define any market with a potential for successful commuter air service. Table 3 summarizes a few of these generalized features which are discussed below.

Major commuter markets and route structures have the common characteristics of connecting outlying communities with a major city or airline hub. Although the purposes for travel may differ, such a population center is fundamental at one or both ends of a commuter route structure. Additionally, the markets must not be a very long distance from this hub. Not only does the propensity for travel to a particular city decrease as distance increases, but commuter air carriers are confronted with passenger tolerance limits associated with long travel times in small, slow aircraft. Noise levels and effects of turbulence are also more pronounced in these aircraft because of their frequent operation at low altitudes. Typical stage lengths flown by commuters range from less than 100 miles to slightly over 200 miles. There is also an effective minimum distance that is necessary to attract a traveler from his automobile or other slower surface transportation modes to commuter air travel. This distance will vary from region to region and is a direct function of trip purpose, available alternative travel modes, relative costs, and travel times. Normally, distances must exceed 50-60 miles to divert a traveler from other modes of ground transportation to air service and may exceed 100 miles in Western regions where travelers are accustomed to driving long distances. Commuter air service is often characterized by necessity rather than convenience, providing essential air service to communities isolated by physical barriers such as mountain ranges or bodies of water, or by a lack of common carrier ground transportation alternatives such as bus or train service.

Routing and service concepts for commuter airlines are usually either "hub and spoke" or "linear" and are characterized by the types of markets they serve. Closein communities geographically located around an airline hub and which generate significant interlining travel (typically 60-70% of commuter users are interlining passengers) will normally be served by a "hub and spoke" route structure, as will be relatively short stage length markets around a hub that may exhibit significant origin and distination travel. Alternatively, smaller communities spaced greater distances from a hub will normally be served by a linear route structure characterized by one or two legs oriented toward "collecting" passengers. Linear route structures are also used to serve smaller communities between two large hubs with scheduling oriented more toward nonstop service in each direction. Finally, some commuter airlines have instituted short distance "shuttle type" service that provides high frequency flights from close-in points to a transportation hub or major population center. Typical examples of these types of route structures as well as the type of patronage served for selected areas of the country are illustrated in Table 4.

- SHORT-HAUL (AVERAGE 1978 STAGE LENGTH WAS 111 miles)
- PROVIDE SERVICE TO RURAL COMMUNITIES WITH FEW COMMON CARRIER TRANSPORTATION ALTERNATIVES
- MINIMUM COMMUNITY DISTANCE FROM POPULATION CENTER OR HUB (DEPENDING ON TRAVEL TIME AND AVAILABLE ALTERNATIVES MODES)
    - EAST – 50-60 miles
    - WEST – 75-100 miles
- PHYSICAL BARRIERS (WATER, MOUNTAINS)
- PROVIDE ACCESS TO MAJOR BUSINESS, RECREATIONAL ATTRACTION, OR AIRLINE HUB

TABLE 3. - SERVICE CHARACTERISTICS COMMON TO COMMUTER MARKETS

TYPE ROUTE	AIRLINE	PREDOMINANT PATRONAGE
HUB AND SPOKE (INTERCITY)	RANSOME (PHILADELPHIA/ WASH., DC)	O AND D*
	AIR ILLINOIS (SPRINGFIELD-CHICAGO)	O AND D
HUB AND SPOKE (INTERCITY)	METRO AIRLINES (HOUSTON/DALLAS-FORT WORTH AREA)	INTERLINE
HUB AND SPOKE (INTRAURBAN)	GOLDEN WEST (LOS ANGELES AREA)	INTERLINE
HUB AND SPOKE (RECREATIONAL)	KEY AIRLINES (SALT LAKE CITY-SUN VALLEY)	INTERLINE
	ROCKY MOUNTAIN AIRWAYS (DENVER COLO-SKI RESORTS)	INTERLINE
	SIERRA PACIFIC (CALIF.-SKI RESORTS)	INTERLINE/O AND D
LINEAR (INTERCITY)	AIR WISCONSIN (WISCONSIN-MINN/CHI)	INTERLINE/O AND D
	CASCADE (EAST. WASH.-SEATTLE/PORTLAND)	INTERLINE/O AND D
	SKY WEST (S. W. UTAH-SALT LAKE CITY)	O AND D
LINEAR (RECREATIONAL)	AIR WISCONSIN (NORTHERN WISC)	O AND D
SHUTTLE (RECREATIONAL)	CATALINA AIR (LONG BEACH-CATALINA IS)	O AND D
SHUTTLE (INTERCITY)	SEAPLANE SHUTTLE (NEW YORK CITY AREA)	O AND D

*O AND D–ORIGIN AND DESTINATION (NON-INTERCONNECTING PASSENGER)

TABLE 4. - TYPICAL COMMUTER ROUTE STRUCTURES

Most commuter operators provide at least two round trips per day between outlying communities and the major population center of interest. These are scheduled to provide a businessman with early morning departures from the outlying community and evening returns, and to provide timely interline connections to serve the interlining passenger. Although most travelers prefer non-stop flights to their destination, some markets and route structures dictate the necessity for enroute stops. More than two enroute stops will almost always seriously degrade patronage.

To further illustrate service characteristics, Table 5 (Reference 4) summarizes the type of service, the number of airlines offering the service and the number of airports and city pairs served. As can be seen from this table, the majority of the airlines concentrate on passenger and cargo service. Such airlines serve 386 airports and 950 city pairs. An additional 187 airports and 145 city pairs are served by 38 airlines that carry passengers, cargo, and mail. Table 6 (Reference 4) illustrates the density of passenger, cargo and mail flow through the various airports served. Of significance, an extremely large number of airports provide a very small number of passengers, cargo and mail. This illustrates the nature of the small community service provided by the the commuter airlines and their need for small, short-haul transport aircraft.

Commuter Aircraft

When scheduled commuter air service was emerging in the 1960s, the aircraft employed consisted primarily of older Beech 18 series twin engine aircraft, a few light twins (e.g., Piper Aztecs) and various single engine aircraft. Whereas local service carriers were able to initiate service in the 1940s with aircraft the same size as the trunk airlines (the DC-3s), commuter airlines were limited to operating smaller aircraft under 12,500 pounds gross takeoff weight unless certification or a special exemption was obtained from the CAB. The low initial cost of these small aircraft was also a primary consideration.

As the industry grew, however, commuter derivatives of more modern executive-configured aircraft having higher density seating were heavily utilized, such as the Piper Chieftan's, Cessna 402s, and Beech 99s. Currently, although a few commuter airlines operate some larger turboprop powered aircraft such as the DHC-7 and HS-748, the majority by far operate aircraft under 30 passenger capacity and 7500 pounds maximum payload - the limit set by the CAB in July 1972 for service without certification or exemption from economic regulation. Until December 1978 an operator of an aircraft exceeding 12,500 pounds maximum gross weight (about 19 passengers) in commuter service had to comply with the more stringent operating regulations imposed by the FAA in FAR Part 121. Recent revisions to FAR Part 135, however, permit operation of up to 30 passenger capacity commuter aircraft but add a number of requirements related to maintenance, flight crew qualifications, training and equipment. Many commuter airlines still prefer aircraft carrying no more than 19 passengers, the maximum allowed by the FAA before a flight attendant is required.

TYPE OF SERVICE	CARRIERS	AIRPORTS	CITY-PAIRS
PASSENGER ONLY	53	94	556
CARGO ONLY	36	82	577
MAIL ONLY	9	42	123
PASSENGER AND CARGO	110	386	950
PASSENGER AND MAIL	7	15	25
CARGO AND MAIL	5	13	17
PASSENGER, CARGO AND MAIL	38	187	145
TOTAL	258	819	2,393

TABLE 5. - COMMUTER AIR CARRIER SERVICE FOR
12 MONTHS ENDED DECEMBER 31, 1978

INBOUND AND OUTBOUND PASSENGERS	NUMBER OF AIRPORTS
500,000 OR MORE	6
200,000 – 499,999	8
100,000 – 199,999	22
50,000 – 99,999	58
25,000 – 49,999	72
10,000 – 24,999	107
5,000 – 9,999	82
LESS THAN 25	327
TOTAL	682

INBOUND AND OUTBOUND CARGO, tons	NUMBER OF AIRPORTS
10,000 OR MORE	8
5,000 – 9,999	9
2,500 – 4,999	16
1,000 – 2,499	25
500 – 999	34
250 – 499	40
100 – 249	81
50 – 99	70
25 – 49	80
LESS THAN 25	305
TOTAL	668

TABLE 6. - DISTRIBUTION OF COMMUTER AIRLINES TRAFFIC VOLUME FOR 12 MONTHS ENDED DECEMBER 31, 1978

Commuter airlines favor twin engine aircraft, with only 18% of the current fleet consisting of single engine aircraft that are selectively employed in the smaller markets. As indicated in Reference 7, passenger acceptance, speed, and capacity considerations preclude any wide employment of single engine 4-6 passenger aircraft. In the 7 to 10 passenger range, the twin-engine Cessna 402 and Piper Navajo are generally preferred because of their seating density and good performance characteristics short of upgrading to turboprop aircraft. The Beech 99, currently not in production but being considered to re-enter production, is the only contemporary aircraft bridging the gap between 10 and 19 passengers and dominates the market for those operators with seating capacities optimal in this range. The pressurized Swearingen Metro is the only current technology aircraft presently produced in the United States to serve the 19 passenger commuter aircraft market. All other current technology short-haul transport aircraft in the 19 passenger and greater capacity range available to satisfy the growing commuter market needs are of foreign design and manufacture. The Canadian deHavilland DHC-6 Twin Otter continues to be extremely popular in the 15 to 19 passenger range due to its high reliability, minimal maintenance, and short field performance, and is highly suited for the shorter haul, higher density commuter markets. The 19 passenger, twin turboprop Brazilian Embraer Bandeirante aircraft is also rapidly gaining the interest of commuter operators in the United States and abroad and, although initially certificated as unpressurized, will soon be available in a pressurized version. The 25-30 passenger French built Nord 262, although no longer in production, is popular in the higher density markets and a limited quantity of a re-engined U.S. modification of the Nord 262, called the Mohawk 298, were introduced by Allegheny Airlines. A recent introduction to the U.S. commuter market is the 30 passenger, unpressurized SD 3-30 commuter/cargo transport aircraft, built by Short Bros., Ltd., of Belfast, Northern Ireland. An aircraft also receiving considerable interest is the 50 passenger, pressurized Dash 7 built by deHavilland of Canada. This four-engine STOL turboprop powered aircraft has been ordered by five of the larger U.S. commuter airlines and is indicative of the trend toward larger aircraft in selected higher density markets. Some of the current commuter aircraft just discussed are pictured on Figure 4, along with their passenger capacity and year of first flight.

Table 7 (Reference 15) identifies the commuter fleet as of June 1978, and Table 8 shows representative aircraft used by commuters for passenger service. As can be seen from Table 8, the more popular contemporary aircraft used for passenger service are the Piper Aztec in the 4-6 passenger capacity range, the Cessna 402B and the Piper Navajo in the 7-10 passenger capacity range, and the Twin Otter and Swearingen Metro in the 16-19 passenger range. Jet aircraft operated by commuter airlines are principally limited to Dassault Falcons and Boeing 727's used by Federal Express in their unique small package cargo operations.

As discussed above, the varied types and sizes of markets results in the utilization of a wide variety of aircraft by commuters. The unique nature of the service provided and the wide variety of market characteristics worldwide

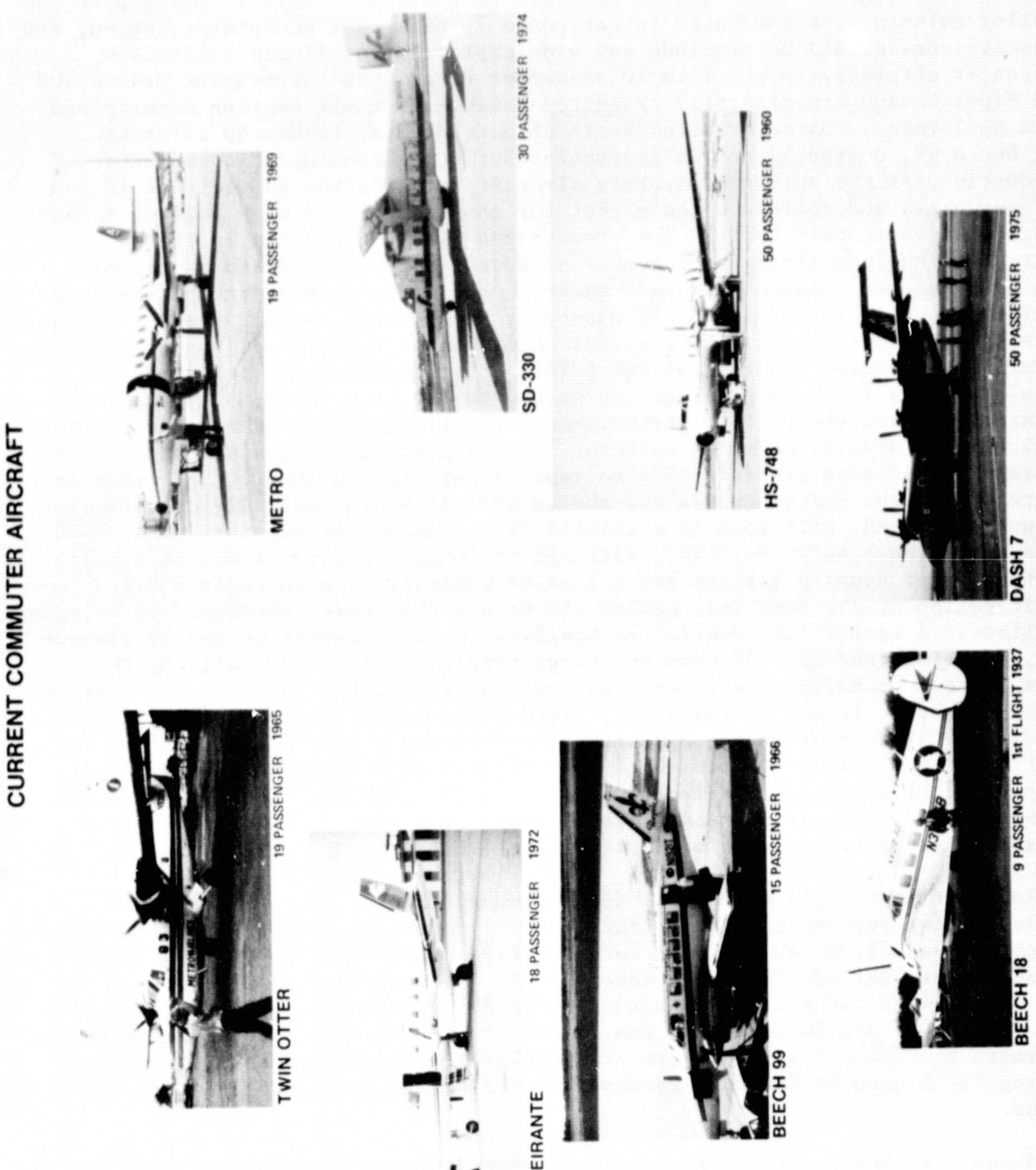

FIGURE 4. - REPRESENTATIVE CURRENT COMMUTER AIRCRAFT

TYPE AIRCRAFT	NUMBER OF AIRCRAFT				
		PISTON ENGINE			
	TOTAL	SINGLE	MULTI	TURBINE	JET
AERO COMMANDER	36	—	36	—	—
AERO STAR (600)	14	—	14	—	—
BEECH	224	25	96	103	—
BOEING	6	—	—	—	6
BRITTEN NORMAN	34	—	34	—	—
CESSNA	231	83	148	—	—
CONVAIR	8	—	7	1	—
DASSAULT (FALCON)	21	—	—	—	21
DeHAVILLAND	116	16	14	86	—
DOUGLAS	71	—	71	—	—
GRUMMAN	26	—	9	16	1
LEAR JET	5	—	—	—	5
MARTIN (404)	18	—	18	—	—
NORD (262)	18	—	—	18	—
PIPER	297	82	215	—	—
SHORT BROTHERS	11	—	—	11	—
SWEARINGEN (METRO)	35	—	—	35	—
OTHER	29*	6	9	9	—
TOTAL	1,200*	212	671	279	33

* INCLUDES 5 HELICOPTERS

TABLE 7. - AIRCRAFT OPERATED BY COMMUTER AIR CARRIERS AS OF JUNE 30, 1978

PASSENGER CAPACITY	AIRCRAFT	IN SERVICE BY COMMUTERS IN 1978
4 - 6	PIPER AZTEC E (TURBO)	55
	AERO COMMANDER	36
	CESSNA 310	23
7 - 10	BEECH 18	93
	CESSNA 402B	116
	PIPER NAVAJO	130
	PIPER SENECA	29
	BRITTEN NORMAN ISLANDER (BNI)	34
11 - 15	BEECH 99	95
16 - 19	DHC-6 TWIN OTTER	86
	DH 114 HERON	14
	SWEARINGEN METRO	35
20 - 30	NORD 262	18
	SD3-30	11
31 - 60	DC-3	13
	CONVAIR 340/440/580	8
	MARTIN 404	18

TABLE 8. - REPRESENTATIVE COMMUTER AIRCRAFT

makes it extremely difficult to produce a single aircraft designed to satisfy the total needs of the industry. Further, the current generation of U.S. produced aircraft in commuter airline use were principally derivatives of general aviation aircraft and, as such, were not designed to withstand the high utilization demanded by commuter transport operations. Thus, a "family" of transport quality aircraft in the 15-60 passenger capacity range and designed specifically to meet the varied requirements of the expanding commuter airlines is needed both in the United States and abroad.

Forecast Growth

The FAA recently completed a comprehensive forecast of the growth of aviation through the Year 1990 (References 5 and 8). This forecast is summarized in Figure 5, which compares the projected percentage growth between 1978 and 1989 for certificated air carriers, general aviation, air cargo and commuter carriers. As can be seen from the figure, over this period the commuter airlines are expected to achieve a 96% growth in the number of operations, a 116% growth in passengers enplaned, and a 163% growth in revenue passenger miles. Figure 6 identifies the detailed forecast for the commuter airlines through 1990. The industry is expected to enplane 16.5 million passengers and to generate over 2 billion passenger miles in 1990.

The current commuter fleet consists of 18% single engine piston aircraft, 56% multi-engine piston aircraft, and 26% multi-engine turbine aircraft. In Reference 5, the FAA projected a change in this fleet mix by 1988 to reflect 5% single engine piston, 60% multi-engine piston, and 35% multi-engine turbine powered aircraft. This projected change in fleet mix by 1988 has been estimated to create a need for an additional 248 aircraft with 20-39 seating capacity for the top 50 U.S. commuter airlines alone. Considering other U.S. and foreign commercial and noncommercial operations resulted in an identifiable market for a minimum of 500-650 aircraft in the 20-39 seat range by 1988 (Reference 9). These commuter airline growth and aircraft requirement predictions may be conservative in view of the recent effects of airline deregulation and the substantial increase in aircraft orders. Recent forecasts (Reference 10) of the market for new light transport aircraft from 1980 to the year 2000 project a world market for 800-3750 aircraft with a capacity of 15-19 passengers, 1147-3000 aircraft with a capacity of 20-39 passengers, and 1026-1500 aircraft with a capacity of 40-60 passengers.

REGULATIONS

Federal regulation of the U.S. scheduled air carriers can be grouped into two categories: (1) economic regulations imposed by the Civil Aeronautics Board (CAB), and (2) safety oriented regulations imposed by the Federal Aviation Administration (FAA) which include aircraft certification and operational standards. These regulations have been significantly changed by the recently enacted "Airline Deregulation Act of 1978" as well as recent (and proposed) FAA rulemakings that are directly related to safety mandates included in the aforementioned act. Figure 7 (Reference 11) summarizes the regulations

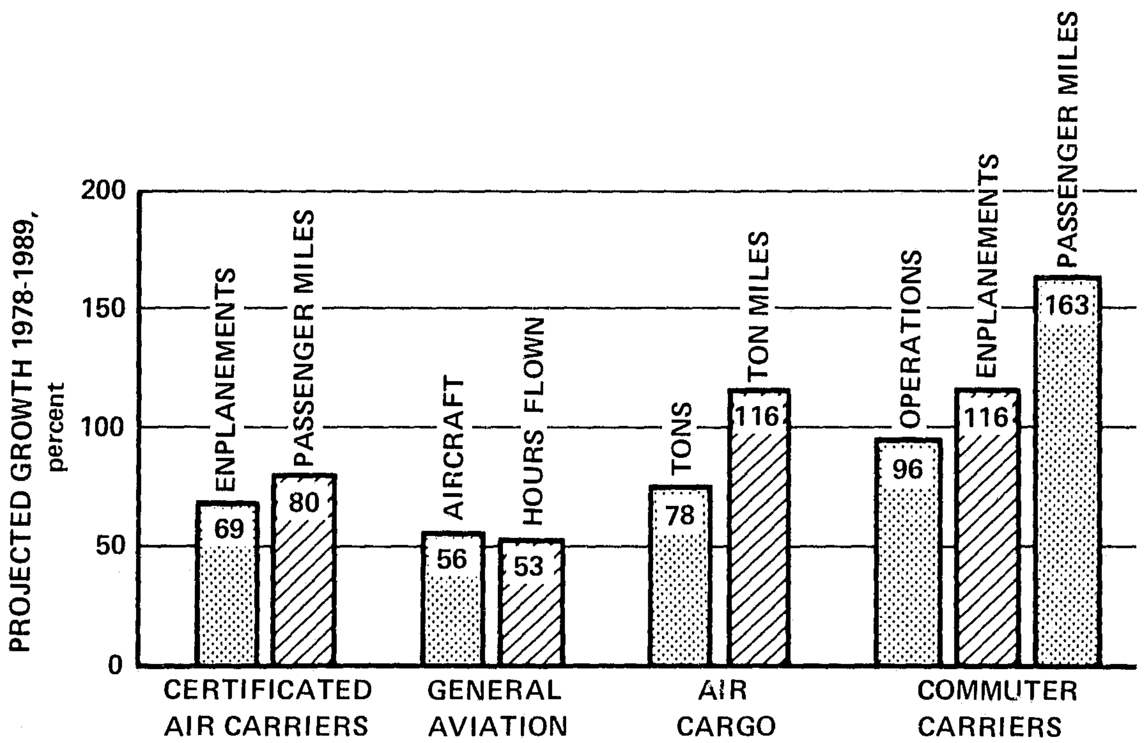

FIGURE 5. - FAA AVIATION FORECASTS

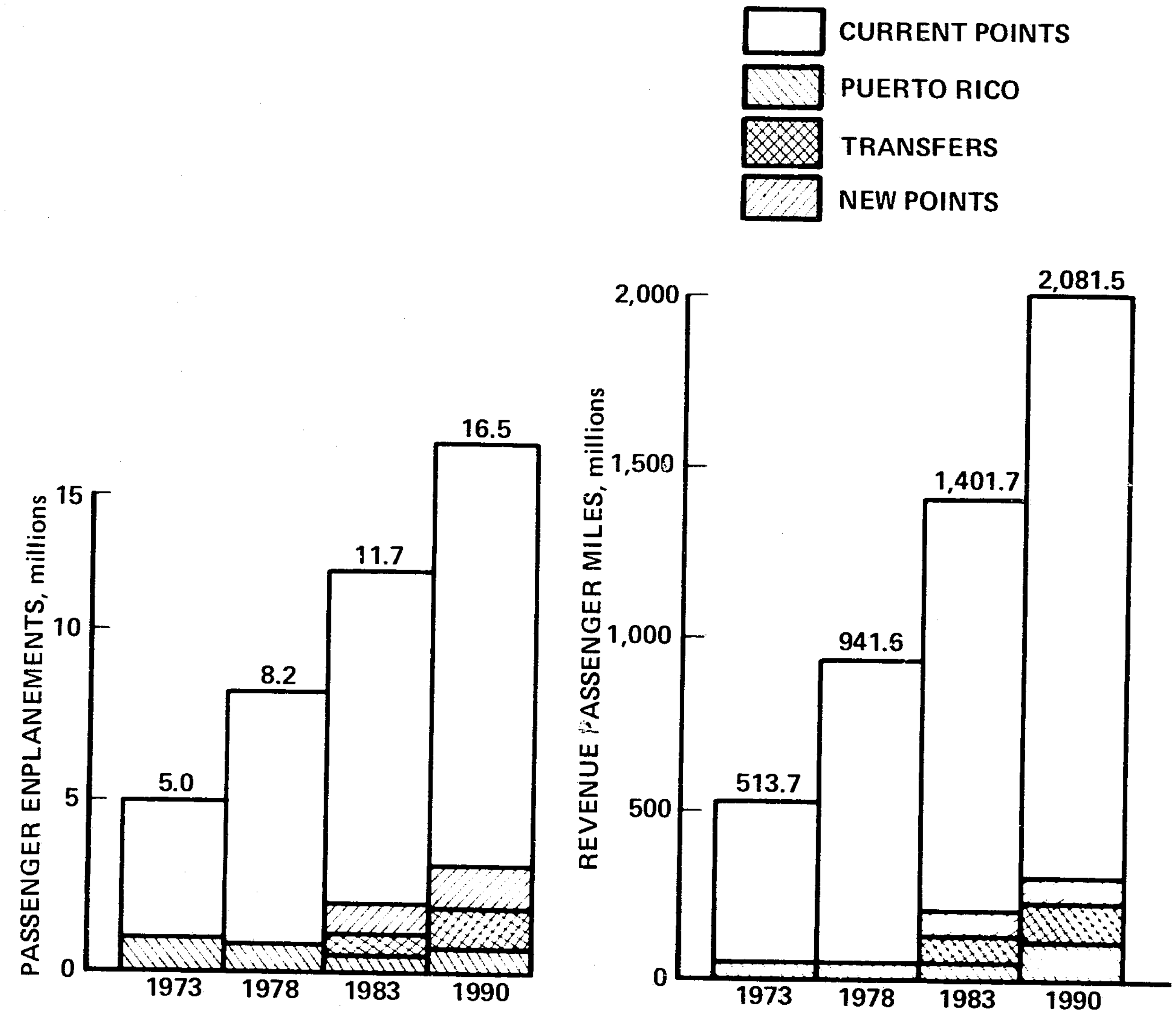

FIGURE 6. - COMMUTER AIR CARRIER PASSENGER ENPLANEMENTS AND REVENUE PASSENGER MILES, 1973 THROUGH 1978 AND FORECAST TO 1990

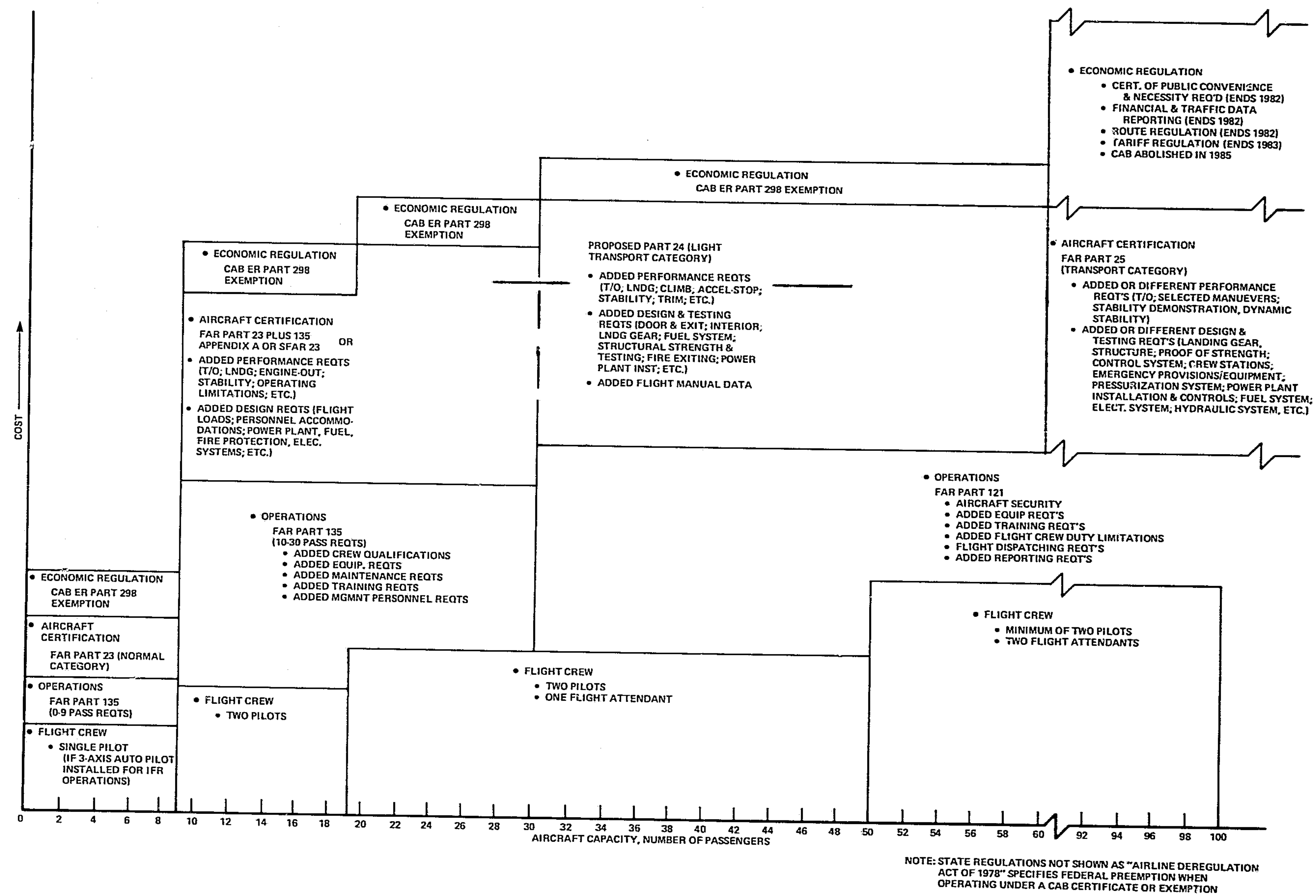

FIGURE 7. - SCHEDULED AIR CARRIER FEDERAL REGULATIONS (ECONOMIC, AIRCRAFT CERTIFICATION, AND OPERATIONAL)

imposed in these two categories on U.S. air carriers. As certificated carriers and commuter air carriers both operate a broad range of aircraft, and regulatory applicability is directly related to aircraft capacity, this figure is structured to indicate regulations as a function of the passenger capacity of the aircraft operated. Also illustrated in Figure 7 is a general indication of the regulatory cost impact as aircraft capacity increases and more stringent regulations are imposed. Although the cost scale is not quantified, it is generally indicative of the relative cost increases as larger aircraft are used (e.g., the largest regulatory cost impact will be for an operator changing from aircraft below 9 passenger capacity to an aircraft capable of carrying over 9 passengers). The regulations depicted in Figure 7 are discussed more thoroughly in the following paragraphs.

ECONOMIC REGULATIONS

Prior to 1952, all carriers engaging in air transportation were required to obtain Certificates of Public Convenience and Necessity from the CAB and were subject to CAB economic regulation. In 1952, the CAB exempted air taxi operators from formal economic regulations via Economic Regulation (ER) Part 298 provided they did not operate aircraft over a somewhat arbitrary 12,500 lb. takeoff gross weight, a limitation designed to avoid unregulated competition with the certificated carriers. Carriers operating under ER Part 298 were, however, required to register with the CAB, carry certain insurance minimums and report certain traffic statistics. The 12,500 lb. weight limit remained unchanged until 1972 when the CAB increased the limit to a maximum passenger capacity of 30 passengers and a maximum payload capacity of 7500 lbs. This revised limit prevailed until passage of the "Airline Deregulation Act of 1978", which permitted operation by commuter air carriers of aircraft up to 55 passenger-seats and up to an 18,000 lb. maximum payload capacity without economic regulation by the CAB. The CAB recently finalized a rule extending the aircraft size to 60 seats. Currently, commuter operators of aircraft with more than 55 passenger seats or 18,000 lb. maximum payload must either obtain a special aircraft exemption from the CAB or obtain and operate under a Certificate of Public Convenience and Necessity which will necessitate that, for the next few years, they comply with certain regulations relating to market entry and exit, fare regulation, and financial and traffic data reporting. The Airline Deregulation Act of 1978 contains "sunset" provisions which mandate that the CAB will cease regulation of market entry and exit and certificate requirements by the end of 1982, and all regulation of fares by the end of 1983. The CAB itself will be abolished by 1985 with continuing necessary functions transferred to other federal departments.

The Appendix of this report summarizes the features of the Airline Deregulation Act of 1978; however, a few key parts of this act that most affect the economic regulation of the commuter airline industry are discussed here. Commuter airlines are now recognized formally as part of the nation's Air Transportation System. They are also eligible for federal loan guarantees to facilitate acquisition of new aircraft and for equal participation in any joint fare program established by the CAB for the certificated airlines.

Also, the CAB is charged in the Act with the establishment of a small community air service program which will guarantee essential air service to certain small communities for a 10-year period, and to provide federal subsidy to any carrier when necessary to maintain "essential air service" to those communities. Further, the air service needs of communities which have had certificated airline service suspended or deleted since 1968 will be reviewed by the CAB and a decision made as to whether any of these communities qualify for "essential air service" under the new, small community air service program. The Act further specifies the conditions whereby certificated airlines can abandon less profitable low density markets and charges the CAB with finding appropriate replacement carriers. Such replacement service will probably provide a signficant number of new market opportunities for the commuter airlines.

OPERATING REGULATIONS

Safety oriented Federal Air Regulations (FAR's) are administered by the FAA. Air carriers are required to operate in accordance with standards established in either FAR Part 121 or FAR Part 135, depending upon the passenger capacity of the aircraft operated.

FAR Part 121 specifies operating standards for carriers operating transport aircraft with passenger capacities greater than 30 or with maximum payloads greater than 7500 lb., and includes all carriers with a CAB Certificate of Public Convenience and Necessity (although certificated operators of aircraft of less than 30 passenger capacity are allowed, per Part 121.9, to operate essentially under the applicable provisions of Part 135). Part 121 imposes more stringent requirements on an operator than Part 135 in the following areas:

- o Additional equipment requirements (emergency equipment, flight data and cockpit voice recorders, etc.)
- o Additional training requirements (specific minimum training times and requirements for more comprehensive training and documentation)
- o Stricter crew flight and duty time limitations
- o Requirements for formal flight dispatching and flight release
- o Security requirements, including passenger screening

Aircraft with a capacity of 30 passengers or less may be operated under FAR Part 135 which establishes standards in the following categories:

- o General rules (certification and operations specifications, manual requirements, management personnel requirements, etc.)
- o Flight operations (record keeping, continuation of flight criteria, use of oxygen, flight crew composition, etc.)
- o Aircraft and equipment (fire extinguishers, cres restraints, oxygen radio, navigational, and emergency equipment, etc.)
- o Operating limitations and weather requirements (VFR/IFR operating limitations, type report and airport requirements, icing condition operations, etc.)
- o Flight crew member requirements (pilot in command certification and experience requirements)
- o Flight and duty time limitations
- o Crew member testing requirements (initial, recurrent, instrument proficiency, line checks, etc.)
- o Training program requirements (documentation, general and emergency training, hazardous material training, pilot and flight instructor proficiency training, ground training, etc.)
- o Airplane operating limitations (takeoff, enroute, landing, etc.)
- o Maintenance and alteration (documentation and reporting requirements inspection, maintenance, preventive maintenance and alteration requirements, maintenance personnel training and qualifications requirements, etc.)

The 10-30 passenger capacity airplane operators are required to conform to the following under FAR Part 135:

- o Fully redundant radio and navigational equipment for extended overwater or IFR operations
- o Shoulder harnesses at flight crew member stations
- o Thunderstorm detection equipment
- o Air Transport Pilot (ATP) rating for the pilot in command
- o An approved continuous maintenance program and associated documentation

Additionally, aircraft having a passenger seating configuration of more than 19 must have a public address system, a crew member interphone system, and certain additional emergency equipment. Turbojet airplanes with more than 10 passenger capacity must also have cockpit voice recorders and ground proximity warning systems.

The requirements applicable to operators of aircraft under 10 passenger capacity are less stringent than those operating aircraft of 10-30 passenger capacities. Deviations to the somewhat comprehensive operations manual requirements are allowed for these smaller (less than 10 passenger) air taxi operators, and they are permitted to operate under an approved inspection program which requires significantly less documentation and record keeping.

Federal regulations specify the number and composition of flight crew personnel as a function of aircraft capacity as shown in Figure 7. A single pilot is permissible under FAR Part 135 for transport aircraft with passenger capacities of less than 10 and a two-pilot operation is required for transport aircraft with passenger capacities of 10 or more. Part 135 and 121 also require one flight attendant for 20-50 passenger capacity aircraft, and two flight attendants for aircraft configured for more than 50 but less than 101 passengers.

AIRCRAFT CERTIFICATION

All U.S. aircraft are certificated by the FAA to various standards of safety based on certain performance, design and testing criteria specified in the Federal Aviation Regulations (FARs). "Large" aircraft, currently defined by the FAA as transport category aircraft with a certificated maximum takeoff gross weight in excess of 12,500 pounds, are certificated under FAR Part 25. Existing "small" transport category aircraft of less than 12,500 pounds were certificated to the less stringent requirements of FAR Part 23. Recently the FAA proposed new certification standards for light transport category airplanes:

° A Special Federal Aviation Regulation, SFAR 23 has been proposed which would allow commuter aircraft having passenger capacities of 10-19 seats to operate in excess of the current 12,500 pound maximum weight limits (up to a zero fuel weight of 12,500 pounds) provided certain additional safety requirements are met. The potential benefit of the proposed SFAR would be to permit operators to install additional avionics, carry additional fuel reserves, and increase passenger amenities without having to off-load revenue passengers on hot or high density-altitude days in order to stay within the current weight limit.

- A FAR Part 24 has been proposed to meet the future needs of commuter airlines and to establish greater levels of safety for aircraft in this category. When finalized and adopted, Part 24 will replace SFAR Part 23 and provide a more comprehensive set of certification standards for light transport category multi-engine aircraft including commuter and short-haul local service transport aircraft up to 30 passenger capacity and about 35,000 pounds gross weight. At the recent Part 24 industry review held in Phoenix in September 1979, the FAA also agreed to consider expanding Part 24 to cover aircraft with passenger capacities of up to 60 with some additional requirements from 30 to 60 seats.

Large transport category airplanes, are, in view of the proposed FAR Part 24, now expected to be defined as airplanes having passenger capacities in excess of 60, and would continue to be certificated to the standards specified in FAR Part 25.

In addition the FAA specifies FAR design and construction standards for aircraft, engines, and propellers, as well as aircraft noise standards. Part 33 specifies airworthiness standards related to engine rating and operating limitations, general design and construction, and block testing. Part 35 specifies general design and construction standards and test requirements for propellers. Part 36 establishes acceptable noise standards for all categories of aircraft including noise limits, noise measurement requirements, and noise evaluation standards.

SYSTEM INTERFACES

This section of the report addresses the system interfaces between individual airlines (e.g., replacement agreements, interline ticketing and baggage agreements, and joint fares); the interface of the airlines with the air traffic control (ATC) system; and the airline interfaces and needs related to airport facilities at large hub airports and smaller community airports, both of which are served by the commuter airlines.

AIRLINE INTERFACES

Replacement Agreements

As mentioned earlier in the report, the trend of the local service airlines to acquire larger jet equipment has resulted in their discontinuing service to many smaller communities where such service was often not economically viable even with subsidy. The CAB, however, required that a replacement carrier be found prior to permitting the local service airline to suspend or delete service. As a result, the local service airlines established a number of formal service replacement agreements with commuter airlines. As of August 1978, some 59 points were being served under such replacement agreements between commuter airlines and eight local service airlines and three trunk airlines. Further, since the commuter airlines had no federally-imposed constraints on entering or leaving markets, the CAB required that the certificated airline remain responsible for serving any market abandoned by the commuter airline and previously served by the certificated carrier. In such cases, the certificated airline was required to reinstitute service within a certain specified time period.

Under the Airline Deregulation Act of 1978, an airline must give 30 to 90 days notice to both the CAB and the affected community before suspending or deleting service below the essential level. The CAB is then responsible for finding a replacement airline within the advance notice period or requiring the current airline to continue service for renewable 30 day periods with compensation for losses.

Interline Ticketing and Baggage Agreements

Trunk and local service airlines who are members of the Air Traffic Conference of America and members of the commuter airline industry have established an Interline Traffic Agreement-Passenger (Reference 6). This agreement gives each participating airline the right to issue tickets and collect revenue over the routes of other participating airlines, accept tickets issued by other airlines and check baggage through to the passenger's final destination. Table 9 summarizes the number of interlining agreements between U.S. certificated airlines and commuters in 1976, 1977 and 1978. In addition, commuter airlines may participate in the International Air Transport Association (IATA) multilateral interline traffic agreements (provided they pay an annual fee based on their total revenue sales) permitting them to interline baggage and freight with international airlines.

Joint Fares

A joint fare agreement is an agreement between participating airlines based on a formula for sharing revenue for the transport of interlining passengers on each of the participating airline's route segment. It is constructed to preclude the passenger from paying the full fare that would be charged for each independent route segment if he were not interlining. The CAB, when establishing joint fare formulae for certificated carriers, previously did not include commuter airlines and, as a result, the commuter airlines were essentially "on their own" when negotiating joint fares with the certificated carriers.

1978 RANK	CERTIFICATED CARRIERS	NUMBER OF AGREEMENTS WITH COMMUTERS		
		1976	1977	1978
1	AMERICAN AIRLINES	34	51	107
2	UNITED AIR LINES	63	95	105
3	EASTERN AIRLINES	50	81	96
4	TRANS WORLD AIRLINES	48	76	94
5	BRANIFF INTERNATIONAL	44	80	91
6	CONTINENTAL AIR LINES	58	86	90
7	DELTA AIR LINES	46	82	89
8	OZARK AIR LINES	48	73	84
9	NORTHWEST AIRLINES	46	71	81
10	WESTERN AIRLINES	31	64	80
11	PIEDMONT AIRLINES	46	70	78
12	ALLEGHENY AIRLINES	37	58	67
13	FRONTIER AIRLINES	32	52	63
14	HUGHES AIRWEST	36	50	59
15	NATIONAL AIRLINES	21	56	59
16	TEXAS INTERNATIONAL	29	47	58
17	SOUTHERN AIRWAYS	33	47	55
18	NORTH CENTRAL AIRWAYS	24	44	47
19	ALASKA AIRLINES	29	46	45
20	AIR NEW ENGLAND	17	37	40
21	PAN AMERICAN	1	35	37
22	AIR MIDWEST	–	26	24

TABLE 9. - SUMMARY OF CERTIFICATED CARRIER INTERLINE AGREEMENTS WITH COMMUTER AIRLINES

Thus, when certificated airlines instituted joint fare agreements with commuter airlines, the revenue share for the commuter airline was often much less than it would have been under the CAB joint fare formula. However, the Airline Deregulation Act of 1978 now requires that any uniform method established by the CAB to calculate joint fares must also apply to commuter airlines.

AIR TRAFFIC CONTROL

The nature of commuter airline operations using small, usually slower aircraft, present different demands on the nation's air traffic control (ATC) system than the certificated airlines operating large jet aircraft. The commuter and local service short-haul airlines generally cruise at much lower altitudes with slower aircraft and over shorter stage lengths as compared to the certificated airlines who fly primarily in positive controlled airspace at relatively high altitudes and cruise speeds, and over long stage lengths. These demands on ATC are magnified in the terminal area airspace of the nation's large hub airports where smaller, slower commuter aircraft must be blended into the pattern with larger, faster jet aircraft. Additionally, many of today's commuter aircraft are not pressurized and therefore are unable to make the rapid descents required by the ATC for optimum handling of terminal area traffic. Further, conducting commuter operations on long runways is a non-optimum use of both air and runway space. The great majority of commuter aircraft do not need the long runways required by the large jet aircraft with their high landing speeds. Very often commuter operators will request ATC permission to use taxiways, shorter runways located on the perimeter of the airport complex, or portions of inactive long runways in an effort to reduce congestion and delays. Taking advantage of the shorter runways at many of the nation's hub airports, and preferably dedicating them exclusively to commuter use, could permit faster arrivals and departures of all aircraft and greatly assist ATC in optimizing airspace and runway usage.

Commuter airlines, by their very nature, must be capable of operating from small community airports as well as from the large, sophisticated hub airports used by the certificated airlines. These small community airports often have only minimal guidance and navigation aids for instrument approaches and landings, a capability considered mandatory by most commuter operators. While precision instrument approach capabilities (e.g. ILS) are highly desirable, realistically they are not economically feasible at many small airports. Considerable interest has been expressed in a relatively low-cost microwave landing system (MLS) for small community airports. Almost all commuter operators have indicated minimum lighting requirements of medium intensity runway lights, rotating beacons, and obstruction lights before instituting service to a small community airport.

FACILITIES

Hub Airports

As stated in Reference 7, a major problem confronting almost all commuter airlines serving large hub airports is their treatment as "second-class citizens" with regards to the allocation of airport space and facilities. They are often relegated to inconvenient and obscure terminal areas within the airport, thus creating a complicated and time-consuming transfer of interlining passengers, which consitute the majority of commuter air travelers, between the commuter and certificated airline gates. A second major problem confronting commuter airlines is the availability of passenger security screening facilities at the hub airports. While commuter passengers are not required to undergo this screening process, the FAA does require screening of all passengers boarding certificated airline aircraft (FAR Parts 121 and 139). This screening process generally precludes any direct transfer of interlining passengers from the commuter aircraft to the certificated airlines aircraft. Instead, it often requires lengthy passenger detours to the certificated airline's gate area in order to pass through the screening equipment. Alternatively, where direct access to sterile areas from the commuter aircraft is possible at the hub airport, many commuter airlines have implemented security screening at the point of origin, usually a small community airport, at increased cost to the commuter airline and, ultimately, to the passengers. In a few cases, the certificated airlines, recognizing the financial advantage from the commuter airline's interlining passengers, are providing financial assistance, or sharing security facilities, gate and terminal space with commuter operators.

Small Community Airports

Many communities served by commuter airlines are small and have airports that just meet minimum requirements for conducting a commercial operation, while other communities, recognizing the value of scheduled commuter airline service, have provided excellent facilities (Reference 7). Among the highly desirable features at small community airports are runway lengths that do not limit safe operation at maximum certificated gross weight on hot, high density-altitude days, such as to preclude having to off-load revenue passengers in order to meet takeoff requirements. The availability of an FAA certified mechanic to handle minor contingencies is highly desirable. Recently, fuel availability has become a major consideration when instituting commuter service to small communities, especially when the current fuel allotment to a community airport, based on a certificated carrier's operations at that airport, is transferred with the certificated carrier when it abandons service to the small community. Community airport facilities can be very limited but should provide sufficient space for passenger service and waiting areas, and importantly, ensure appropriate separation between the public and commuter office areas to facilitate operator privacy in their day-to-day flight planning operations.

TECHNOLOGY NEEDS

BACKGROUND

NASA, the CAB, and the FAA, recognizing that the growing commuter airline industry would have unique requirements in such areas as aircraft design and performance, avionics, and certification, conducted studies as far back as 1969 to identify these special needs (Table 10).

The Civil Aviation Research and Development (CARD) policy study, performed jointly by the NASA and DOT in 1971, identified three major problems facing civil aviation; these were: aircraft noise, airport congestion, and service to small communities. A major conclusion of the study was that solutions to problems of providing efficient, scheduled service to small, low-density communities would have to be found since such service was vital to the continued growth of civil aviation in America. Concurrent with the CARD study, the Aviation Advisory Committee (AAC) formulated recommendations addressing the long-range needs of civil aviation. Their findings identified eight primary areas that would, if not addressed, constrain the growth of the civil aviation system in America. One such area was service to small communities.

Studies initiated by the NASA and DOT in 1972 to identify short-haul aircraft technology needs and define research goals clearly indicated that this could only be done by considering the importance of other related factors such as regulation, certification, and environmental and economic issues. As a result of these concerns, a workshop sponsored by the NASA and DOT was conducted in 1973 to address the broad problems and issues that affect the near and far-term needs of air transportation to the nation's small communities. The issues addressed and recommendations resulting from this workshop included research and technology needs, regulation of local service and commuter airlines, certification criteria, equipment financing, subsidy requirements, and policy and legislation necessary to establish the commuter airlines as an integral part of the national air transportation system. An overall view of the perceived problems restricting improved small community air service is shown on Table 11. These problems encompass concerns about aircraft economics, effects on society, and system integration as viewed by the airline, manufacturer, passenger, community, and operating authorities.

In 1974 and 1975, the McDonnell Douglas Company, under a NASA contract, and the Boeing-Wichita Company, with internal funding, independently investigated the aircraft technology requirements for the U.S. regional airlines into the 1980s. The resulting designs were similar, 50 passenger, turbofan powered aircraft having field length capabilities of 4500 feet and ranges up to 850 nautical miles. The studies also identified some operational and design features that could help reduce the initial and operating costs for this class of aircraft. However, the aircraft cost was estimated to be over $100,000 per seat and judged too expensive to be economically feasible for operation on the short-haul, low-medium traffic density markets for which they were intended.

DATE	TITLE	SPONSOR
NOV 1969	An Analysis of Scheduled Air Taxi Operations	CAB, Bureau of Operating Rights
JUL 1970	Western Region Short Haul Air Transportation Program	States of Idaho, Colorado, Arizona, Nevada
NOV 1970	The U.S. Commuter Airline Industry - It's Current Status and Future Outlook	FAA, Office of Aviation Economics
MAR 1971	Joint DOT-NASA Civil Aviation Research and Development Policy Study	NASA and DOT
OCT 1972	Study of Low-Density Air Transportation Concepts	NASA-Ames Research Center
FEB 1973	Analysis of Carrier Support (COD) Aircraft for Civil Applications	NASA-Ames Research Center
JUN 1973	Washington State Airport System Plan	State of Washington
AUG 1973	Workshop on Low/Medium Density Air Transportation at Aspen, CO	NASA and DOT
SEP 1973	Aircraft Requirements for Low/Medium Density Markets	NASA Headquarters
AUG 1974	Commuter Air Carriers - An Overview	FAA, Office of Aviation Policy
FEB 1975	Pacific Northwest Region Air Service Project	States of Idaho, Oregon, Washington
MAR 1975	Analysis of Operational Requirements for Medium Density Air Transportation	NASA-Ames Research Center

TABLE 10. - STUDIES RELATED TO COMMUTER AND LOCAL AIR SERVICE

DATE	TITLE	SPONSOR
MAY 1975	Oregon Commuter Air Service Project	State of Oregon
SEP 1975	Study of Short-Haul Aircraft Operating Economics	NASA-Ames Research Center
DEC 1975	Operational Factors of Air Service to Small Communities	NASA-Ames Research Center
DEC 1975	Old West Region Commuter Air Service Feasibility Study	States of Montana, Wyoming, Nebraska, North & South Dakota
FEB 1976	The Impact of Commuter Airlines in Short-Haul Major Hub Markets	CAB, Bureau of Operating Rights
MAR 1976	Air Service to Small Communities	DOT, Office of Transportation Regulatory Policy
MAY 1976	Study of Short-Haul Aircraft Operating Economics Phase - II	NASA-Ames Research Center
DEC 1976	A Study of Commuter Economics	NASA-Ames Research Center
JUN 1977	A Study of Commuter Air Service	NASA-Ames Research Center
NOV 1977	Determination of Flight Equipment Maintenance Costs of Commuter Airlines	NASA-Ames Research Center
NOV 1977	Symposium on Small Community Air Service at NASA-Ames	NASA-Ames Research Center
NOV 1977	Study of the Application of Advanced Technologies to Small, Short-Haul Transport Aircraft	NASA-Ames Research Center
FEB 1978	The Commuter Airlines - The Growth Potential, Regulatory Outlook and Equipment Needs	Business and Commercial Aviation Magazine

TABLE 10. - CONCLUDED

SUMMARY OF PERCEIVED PROBLEMS

- ECONOMIC
  - OPERATOR
    - AIRCRAFT INITIAL COST & FINANCING
    - OPERATING COSTS (PARTICULARLY FUEL & LABOR)
    - GOVERNMENT SUBSIDY
    - AIRCRAFT UTILIZATION
    - REGULATIONS UNCERTAINTY, ROUTE PROTECTION
  - MANUFACTURER
    - UNCERTAIN MARKET, DIFFICULT TO AGGREGATE
    - CERTIFICATION COSTS
    - MANUFACTURING COSTS
    - REGULATIONS UNCERTAINTY
    - UNCERTAINTY AS TO OPERATORS ABILITY TO FINANCE
- SOCIAL
  - PASSENGER
    - COMFORT, DEPENDABILITY, SAFETY, FREQUENCY OF SERVICE, FARE
  - COMMUNITY
    - NOISE, EMISSIONS, SAFETY
- SYSTEM
  - ATC INTERFACE
  - RUNWAY SEPARATION
  - TERMINAL FACILITIES & SECURITY REQUIREMENTS
  - PASSENGER & BAGGAGE TRANSFER

TABLE 11. - SUMMARY OF PERCEIVED PROBLEMS IN COMMUTER AIR TRANSPORTATION

An examination of aircraft price versus passenger capacity (Figure 8) indicated that the commuter airlines were more likely to buy and operate aircraft which cost around $50 - 60,000 per seat. In an effort to investigate technology which could reduce aircraft initial cost, a NASA contracted study of low-cost aircraft manufacturing techniques was conducted in 1976 and 1977 with the Boeing Commercial Airplane Company. Based on only a 200 airplane production program, this study indicated that the use of current state-of-the-art large bonded aluminum honeycomb panels for primary and secondary structure could significantly reduce airframe manufacturing cost by 40% and result in a 16% savings in total aircraft cost. The results of this study were presented at a symposium on small community air service sponsored by the NASA Ames Research Center in 1977. This symposium was attended by representatives of government, large and small aircraft manufacturers, and airlines. The symposium recognized the commuter airlines as a vital, growing segment of our national air transportation system, and agreed on the need for the family of new, small, efficient, transport aircraft tailored to the requirements of the commuter and short-haul local service markets.

As discussed previously in this report, a number of recent social, economic and regulatory changes have occurred that impact the growth and national necessity of commuter airlines. Joint fare agreements between commuter and certificated airlines have reduced the additional cost to the commuter air traveler for use of commuter airlines from small communities for connections with the long-distance trunk airlines at hub airports. Regulatory changes have been enacted to establish the commuter airlines as full partners in our national air transportation system. The operating requirements, Part 135 of the Federal Aviation Regulations (FAR), have been revised to improve the safety of commuter air carriers and allow operation of aircraft with up to 30 passenger capacity. Certification requirements, under a proposed new FAR Part 24, have been drafted that create appropriate standards for a new categroy of light multi-engine transport airplanes, and are currently in the review process. The Airline Deregulation Act of 1978 established a new Small Community Air Service Program whereby the CAB, working with approximately 700 small communities, will determine the essential level of air service required by these communities and will ensure that this level of service, as a minimum, is provided and maintained. Additionally, the energy crisis and subsequent restricted availability and increased cost of automobile fuel have spurred passenger travel by commuter airlines for short trips. These regulatory changes coupled with increased passenger acceptance of commuter air travel have resulted in a strong demand for new, improved commuter aircraft and have significantly improved the opportunities for application of advanced technology to the design of these aircraft.

The commuter and short-haul local service airlines in America are currently operating a wide variety of small domestic and foreign aircraft, most of which were originally designed for the general aviation market, and which are operationally and economically severely compromised for commuter airline operations. Despite the relatively wide selection of foreign, small, short-haul transport aircraft available to commuter airlines, the 19 passenger Swearingen Metro, introduced into service in 1971, is the only current technology, short-haul

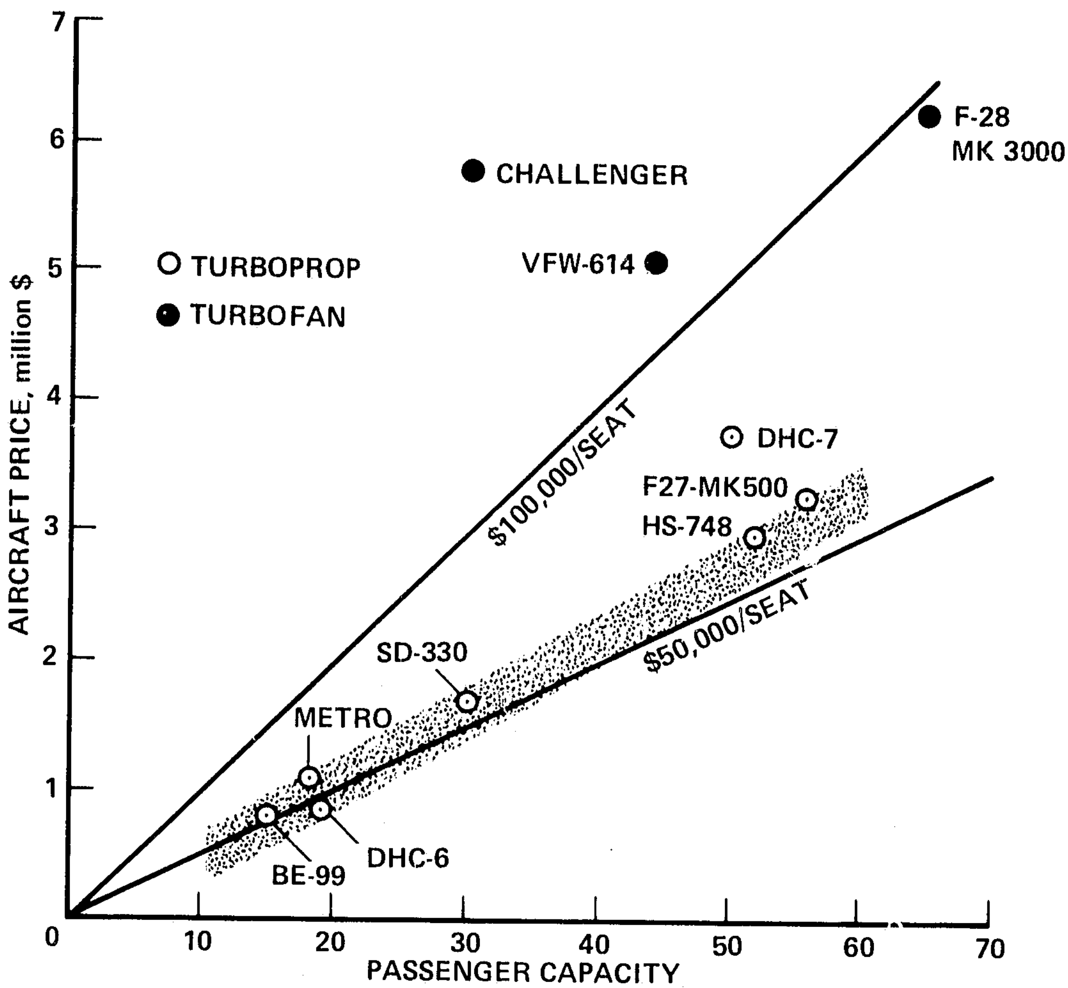

FIGURE 8. - AIRCRAFT PRICE COMPARISONS -
1977

transport aircraft in the small, 15 to 60 passenger capacity range, being produced in the United States today. All other current technology small, short-haul transport aircraft in production and available to fill the growing needs of the rapidly expanding commuter and short-haul local service markets are of foreign manufacture.

INDUSTRY COMMENTS

In an effort to better address the concerns of the Senate Committee on Commerce, Science, and Transportation, and to insure that the most appropriate small transport aircraft research and development efforts are considered, NASA has visited most of the potential U.S. manufacturers, several commuter and local-service airlines, and other organizations. The manufacturers visited are listed on Table 12. Although not shown on this table, information was also obtained from the Boeing-Seattle, Douglas, and Lockheed-California Companies.

The manufacturers' comments are summarized on Table 13. The manufacturers see the importance of an advanced technology data base which they could use for the design of future small transport aircraft. This data base should be specifically focused on the operational needs of small transports because the nature of compromises between performance and cost for these aircraft differs considerably from those for large, long-range aircraft or small, general aviation aircraft. This results from the unique design requirements and more severe operational requirements of the small passenger capacity commuter aircraft which are geared to providing frequent, scheduled service to many low density, short-haul markets. Of prime importance in their design are simple, reliable, easily maintainable airframes, engines, avionics, aircraft systems, as well as low initial and operating costs. Structurally, because of frequent daily operations over short stage lengths in a low altitude environment, the aircraft must be designed to withstand many more takeoff and landing cycles per flight hour than larger transport aircraft. Operationally, commuter aircraft must be capable of operating from small community airports with short runways and minimum navigational aids as well as from the large, sophisticated hub airports used by the trunk and local airlines, and be able to effectively integrate their operations with those of the certificated carriers and the air traffic control systems at these large airports. Emissions and external and internal cabin noise must be reduced to enhance community and passenger acceptance, and to increase passenger comfort. Many of the technology advances necessary to bring about these improvements have recently been identified (Reference 12).

As shown on Table 13, structural design data is needed on advanced composite materials. Although there are currently substantial composite material technology efforts underway, they are focused on large transport and military applications. In order for the small aircraft manufacturers to take advantage of this advanced materials technology, they need basic composite design

BEECH AIRCRAFT COMPANY
CESSNA AIRCRAFT COMPANY
GATES LEARJET CORPORATION
SWEARINGEN AIRCRAFT COMPANY
GULFSTREAM AMERICAN CORPORATION
PIPER AIRCRAFT COMPANY
LOCKHEED-GEORGIA COMPANY
ROCKWELL INTERNATIONAL
GENERAL DYNAMICS-CONVAIR
BOEING-WICHITA

TABLE 12. - MANUFACTURERS VISITED TO DATE

TECHNOLOGY NEEDS

- MORE DESIGN DATA ON COMPOSITES
- MORE DESIGN AND COST DATA ON TECHNICAL APPROACHES TO LOW-COST MANUFACTURING
- MORE AERODYNAMIC DATA ON TURBOPROP ENGINE/AIRFRAME INTEGRATION
- AIRFOIL AND WING DESIGN DATA FOR LOW DRAG AND IMPROVED CLIMB PERFORMANCE
- SIMPLE HIGH-LIFT DEVICES
- HIGHER PERFORMANCE PROPELLERS (COMPOSITE BLADES)
- LOW COST ENGINES
- SIMPLE, RELIABLE AND EASY TO MAINTAIN AIRFRAME, ENGINE, AND AVIONICS

OTHER COMMENTS

- $55,000/SEAT IS A TOUGH GOAL
- PASSENGER APPEAL AND COMMUNITY NOISE IMPORTANT
- WHAT WILL CERTIFICATION REQUIREMENTS AND COSTS BE FOR NEW TECHNOLOGIES
- MARKET STRONG AND GROWING, BUT DEVELOPMENT COSTS A PROBLEM
- OPERATING COSTS VERY IMPORTANT

TABLE 13. - MANUFACTURERS' COMMENTS

and application data. The manufacturers also need aerodynamics design data which could be used to increase the efficiency and climb performance of twin-engine, turboprop powered, small transports. This data could be generated using NASA's advanced computer design optimization methods coupled with wind tunnel tests to provide design information for improved airfoil and wing design, turboprop engine/airframe integration, high-lift component and system design, and advanced propeller design. Propulsion research is required to identify the improvements in engine components which can reduce engine cost and maintenance and improve fuel efficiency. Other comments from the manufacturers indicated their concerns about high development costs for a new aircraft, high certification costs related to new technologies, and a recognition of the importance of passenger appeal, community noise, and aircraft operating costs... all of which are technology dependent or technology related.

The airlines visited directly by NASA personnel for detailed discussions of small transport technology needs are listed on Table 14. A brief summary of the airline comments are listed on Table 15. As shown, the airlines were critical of the lack of available commuter transport aircraft and reliance on general aviation derived commuter aircraft that were not designed with the durability and maintainability necessary for commuter operations. Further, they perceived a gap in the current U.S. manufacturers' capability for building new, small, short-haul transport aircraft in the 15-60 passenger capacity range. Swearingen Aviation is the only U.S. manufacturer of a current-technology, 19 passenger transport...the Swearingen Metro...while the next larger size U.S. built "small" transport is the 95 passenger, turbofan powered, Douglas DC9-30, which far exceeds commuter airline requirements. This "gap" in new, small, short-haul transport aircraft is currently being filled by foreign manufacturers aircraft such as the Shorts SD3-30 (Northern Ireland), the DHC-6 and DHC-7 (Canada), the Embraer Bandeirante EMB 110 (Brazil), and the Fokker-VFW F-27 (Netherlands). Many commuter aircraft currently in use are operationally limited by their original certification limitation to less than 12,500 lb. gross weight, and cannot carry their full passenger capacity with full fuel, particularly when the aircraft performance is reduced on hot days or at high altitudes. Although most commuter airlines would prefer to keep the aircraft acquisition cost at current levels, they recognize that with reasonable financing the overall operating costs become most important. For these reasons and for lack of suitable transport aircraft, some of the smaller airlines are now purchasing larger, more expensive aircraft such as the Canadian de Havilland DHC-7 at a cost of nearly $100,000 per seat.

Other airline comments indicate a preference for twin-engine turboprop configurations (in recognition of the turboprop fuel economy relative to jets); a concern about reliability and maintenance complexity - particularly as it might affect flight delays; a desire for pressurization and an improved passenger cabin environment; and a concern about the air traffic control delays, slot allocations, gate positions, and counter space at hub airports. Although it is recognized that pressurization is desirable from a passenger comfort standpoint, a recent CAB staff study (Reference 13) recommended that it should not be required for aircraft eligibility in providing subsidized, essential small community air service, but should be an airline decision based on economic and competitive considerations.

AIR WISCONSIN
MIDSTATE AIRLINES
NORTH CENTRAL AIRLINES
SMB STAGELINES
FEDERAL EXPRESS
ROYALE AIRLINES
METRO AIRLINES
TEXAS INTERNATIONAL AIRLINES
TEJAS AIRLINES
AIR ILLINOIS
SKYWAY AIRLINES
HENSON AVIATION
COCHISE AIRLINES
GOLDEN WEST AIRLINES

TABLE 14. - AIRLINES VISITED TO DATE

- CURRENT GENERAL AVIATION DERIVED COMMUTER AIRCRAFT ARE NOT ADEQUATE FOR AIRLINE TYPE UTILIZATION (NEED 3000 HR/YR UTILIZATION—NOT 300 HR/YR)
- NEED 19-30 PASSENGER AIRCRAFT CAPABLE OF UNRESTRICTED OPERATION WITH FULL PASSENGER LOAD AND BAGGAGE
- MAXIMUM ACQUISITION COST SHOULD NOT EXCEED $50,000-60,000 PER SEAT
- GAP IN U.S. AIRCRAFT MANUFACTURERS' CAPABILITY

  LARGE JET TRANSPORT (BOEING, DOUGLAS, LOCKHEED) ←——→ SMALL GENERAL AVIATION (BEECH, CESSNA, PIPER)
- STRONGLY PREFER TWIN ENGINE TURBOPROP CONFIGURATION
- MUST KEEP AIRCRAFT AND SYSTEMS SIMPLE, LOW COST, RELIABLE AND EASY TO MAINTAIN
- OPERATIONAL READINESS CRITICAL—SHORT-HAUL SERVICE EXTREMELY SENSITIVE TO ANY DELAYS AFFECTING ON-TIME SERVICE
- DESIRE IMPROVED PASSENGER COMFORT FEATURES (PRESSURIZATION, AIR CONDITIONING, ETC)
- NEED EFFECTIVE INTEGRATION WITH LARGER CARRIERS AND ATC AT HUB AIRPORTS

TABLE 15. - AIRLINE COMMENTS

Additional comments received from other organizations are shown in Table 16. The Commuter Airline Association of America (CAAA) endorsed the comments of the airlines and expressed a particular concern about hub airport restrictions on commuter operations. Because the major portion of the commuter business involves connections with other airlines at hub airports, it is extremely important that such airport access be available. The General Aviation Manufacturers Association (GAMA) endorsed the comments of the manufacturers and strongly supported a focused technology data base development program similar to the early NACA research approach. The Civil Aeronautics Board (CAB) felt there is a constraint on their efforts to insure essential small community air service, as mandated by the Airlines Deregulation Act of 1978, by the current lack of available high quality small transport aircraft.

STAT

The important aircraft design and operational factors that impact the passenger acceptance and operational economics are illustrated on Figure 9. Passenger and community acceptance is dependent on convenience, dependability, speed, ride quality, noise and emissions, and fare. The passenger is sensitive to both the convenience of the overall commuter airline service (frequency, location of terminal, baggage handling, etc.) and the convenience of aircraft entry and exit. Because most commuter airline flights are short-haul and provide connecting service with other airlines, on-time dependability is of paramount importance. A 30 minute delay is much more detrimental to a 30 minute short-haul flight than to a 5 hour long-haul flight, especially if it results in a missed connection. Although speed is certainly important to the passenger, particularly for the longer commuter flights, is is more important to the operator because of its direct effect on aircraft productivity and, hence, on operating cost. A savings of a few minutes on each leg of a short-haul flight can result in a significant increase in aircraft productivity over a day's operation. Many passengers remain somewhat nervous about flying, especially in many of the "non-airline" looking commuter aircraft, and appreciate as smooth a ride as possible. Unfortunately, because most current commuter aircraft have low wing loadings and spend a large portion of flight time in the more turbulent lower altitudes, their ride quality is not as smooth as that of the larger jet transport aircraft. Seating comfort; the provision of adequate storage areas for coats and carry-on baggage; good ventilation, heating, and air conditioning; and pressurization also contribute to improved ride quality and passenger satisfaction. The requirement for a quiet interior environment has also grown in importance, particularly as the typical stage lengths have increased (Reference 14) while low exterior noise and emissions are important for community acceptance.

- CAAA – CONCERNED ABOUT HUB AIRPORT RESTRICTIONS ON COMMUTER OPERATIONS
- GAMA – STRONGLY SUPPORTS TRADITIONAL NACA FOCUSED TECHNOLOGY DEVELOPMENT
- CAB – VIEWS LACK OF HIGH QUALITY SMALL TRANSPORT AIRCRAFT AS A MAJOR CONSTRAINT TO IMPROVED SMALL COMMUNITY AIR SERVICE

TABLE 16. - OTHER COMMENTS

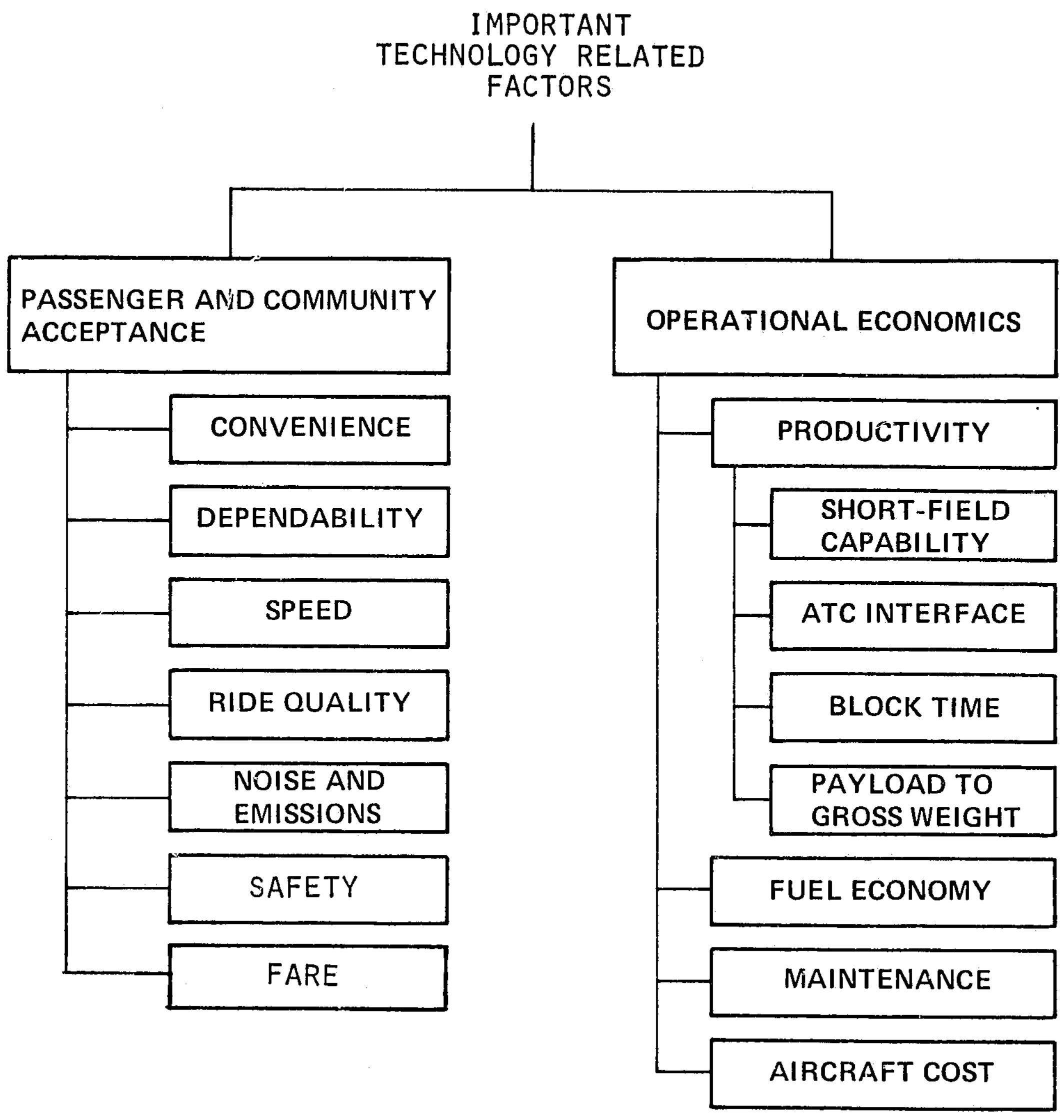

FIGURE 9. - IMPORTANT SMALL TRANSPORT AIRCRAFT
TECHNOLOGY RELATED FACTORS

The aircraft operational economics are a function of the aircraft productivity, fuel economy, maintenance cost, and initial aircraft cost. Aircraft productivity is influenced by aircraft performance capabilities which may allow it to be operated from short runways with full payload, to avoid delays by integrating smoothly into the air traffic control (ATC) system shared with larger aircraft, to cruise at high speeds to minimize block time, and to have improved climb performance to allow increased aircraft payload to gross weight. With continuing increases in fuel prices, fuel economy is a major operating cost concern. Most operators have traditionally placed critical emphasis on low acquisition costs; however, as capital becomes more available, the overall operating cost is becoming more important. All of those factors which can improve passenger acceptance must be evaluated against their effect on the aircraft operational economics, and hence, on fare.

In order to assess these trades and identify and pursue the most promising small transport aircraft technology opportunities, a "Small Transport Aircraft Technology" (STAT) activity has been initiated within NASA. It is aimed at the definition of appropriate advanced technologies for application to new, small, short-haul transport aircraft having significantly improved performance, efficiency, and environmental compatibility. Although many details of STAT research are still being considered, it appears that NASA's technical expertise in aerodynamics, propulsion, and aircraft systems might lead to significant technology developments for potential near-term application to derivatives of existing commuter aircraft or current state-of-the-art, new, short-haul, transport aircraft designs.

Unique STAT research needs are being investigated in the broad technology application study contracts that have recently been awarded to several airframe, engine, and propeller manufacturers. In addition, the technology needs for small, short-haul transport aircraft that are not unique and may be satisfied by applying the results from other on-going and planned NASA programs will also be indicated. In these studies, the design and operational characteristics that constitute the main constraints to improved cruise and terminal area performance will be identified and examined. These include such factors as high drag, high/low speed ride quality, noise, and emissions. The potential for improvement by the cost-effective application of advanced technology will be evaluated. Such improvements will be estimated in terms of increased efficiency; improved external noise and emissions; increased passenger comfort (reduced cabin noise, vibration, and ride roughness); and improved terminal area capability. The studies will define the research and development required to elevate the appropriate advanced technology to the point that it could be applied to new aircraft with confidence. Further, recognizing that there will be long term technology needs, these studies will also address all of the aeronautical technology disciplines of aerodynamics, propulsion, aircraft systems, and structures in order to define those advanced technologies that could have a significant impact, in the long term, on future designs of new, short-haul transport aircraft.

The certification requirements and criteria for advanced technology are a particular area of industry concern that influences the acceptance of some otherwise promising advanced technologies. These certification uncertainties should be investigated for the advanced technologies considered and appropriate research should be defined. This research might include reliability assessments and recommended redundancy or monitoring requirements; fatigue, lifetime, and failure prediction; and performance criteria. The evaluation of certification criteria would be coordinated and conducted with the FAA, and selected advanced technologies might be applied to a flightworthy, current state-of-the-art, civil, small, short-haul, transport aircraft. In this way, the actual benefits to be obtained from the advanced technology application could be evaluated and demonstrated with full-scale wind tunnel tests and selected flight tests.

A preview of proposed research which could be conducted and some of the precursor research that has already begun is presented herein for each of the following principle technology areas: Aerodynamics Technology, Propulsion System Technology, Aircraft Systems Technology, and Structures Technology. The overall goals and principal technology areas are illustrated on Figure 10.

Aerodynamics Technology

The small passenger capacities and short stage lengths of commercial small transport aircraft are the major factors that make operational costs of prime importance. These costs might be significantly reduced through the application of advanced aerodynamic technology that would provide improved cruise efficiency, thus reducing fuel costs; improved second-segment climb performance, thus increasing payload capability; and improved takeoff and landing performance capability, thus reducing block time. Additionally, improved terminal area operational capability would aid in reducing airport congestion. The primary aerodynamic technology areas are illustrated in Figure 11.

Detailed aerodynamic analyses, selected small-and large-scale wind tunnel experiments, and selected flight tests could be conducted to develop an aerodynamic analysis data base for improved airfoils and wings designed for reduced cruise drag and/or increased low speed lift and lift/drag ratio. Aerodynamic analysis methods could be developed for the improved performance prediction and design of multi-element, high-lift devices. These analytical methods could be compared with small- and large-scale wind tunnel test results and could be used to develop improved, less complex, high-lift system designs offering increased lift and lift/drag ratio during takeoff and climb. The emphasis on the climb condition reflects the fact that most small transports are twin-engine aircraft and the second-segment climb condition is an important sizing constraint. Preliminary aerodynamics research has been initiated to explore the potential for improvements in airfoils, high-lift devices, and wing configurations.

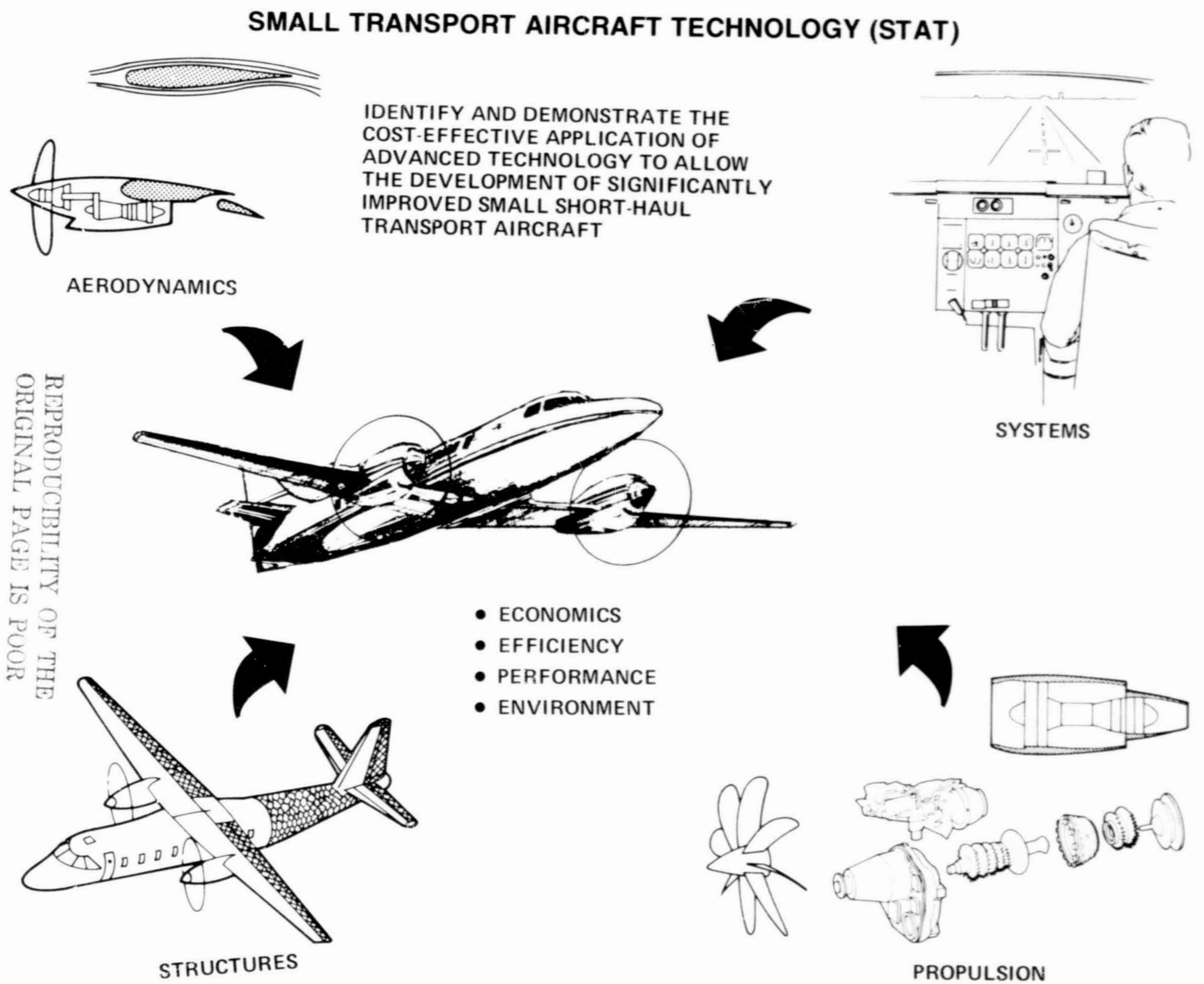

FIGURE 10. - SMALL TRANSPORT AIRCRAFT TECHNOLOGY (STAT)

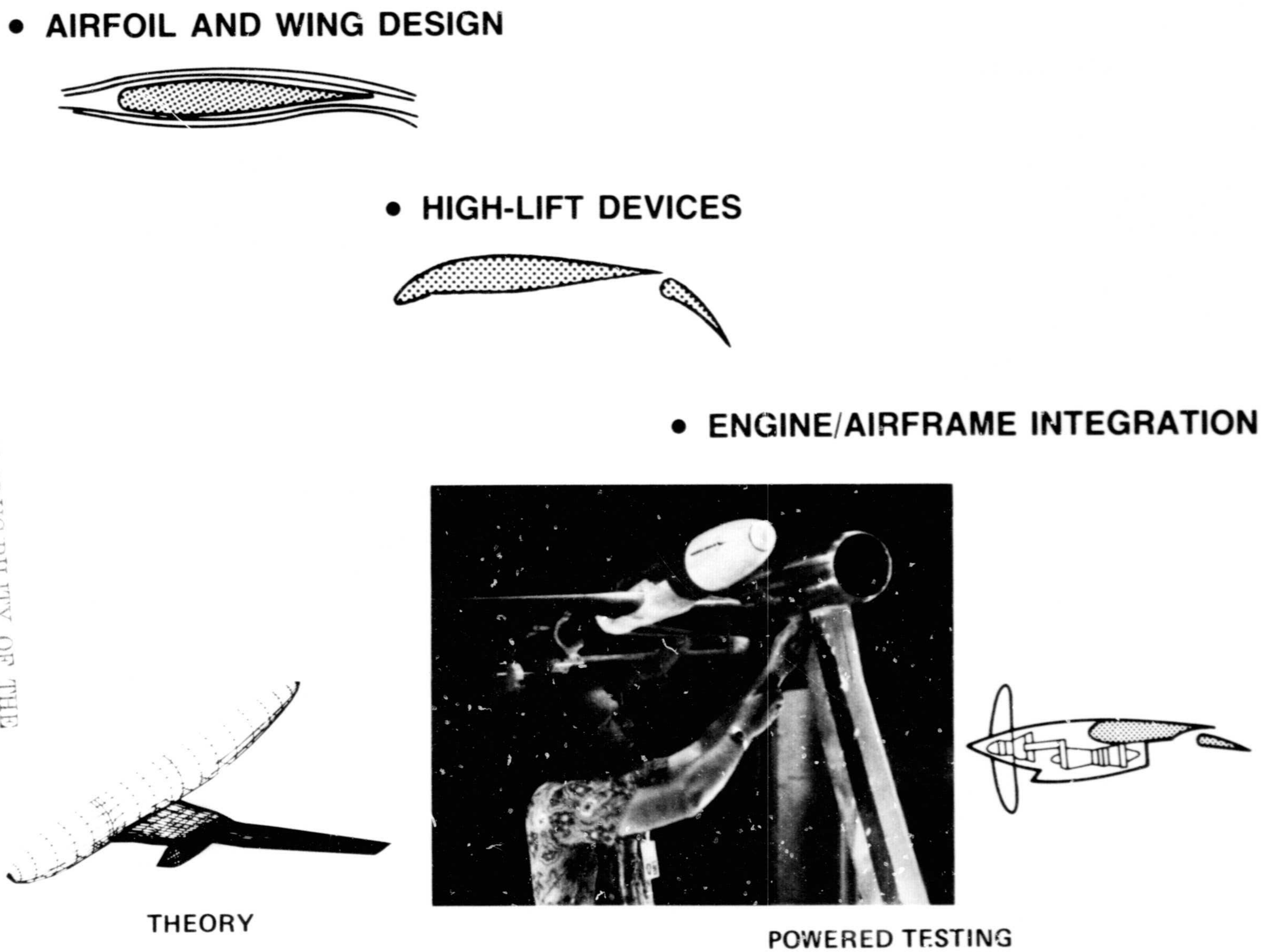

FIGURE 11. - AERODYNAMICS TECHNOLOGY

Analysis and wind tunnel tests could be conducted to investigate turboprop slipstream effects on the aircraft aerodynamics, and to develop design information for alternate improved turboprop/wing installation configurations. The analytical methods could make use of ongoing developments in numerical fluid flow analysis capability. The wind tunnel tests could use a recently developed propeller slipstream simulator in combination with powered models. Exploratory research has been initiated in this area.

The aerodynamic research could be compared with theoretical predictions and related to a current technology data base which will be established by wind tunnel tests of a 15% scale powered model of the Swearingen Metro transport airplane, under a cooperative research program with the Swearingen Aviation Corporation. The final products of this aerodynamic research could be improved theoretical prediction capability and advanced technology designs for airfoils, wings, high-lift devices, engine/airframe integration, and complete small transport aircraft configurations. The theoretical predictions could be verified by large scale testing in the 40-by 80-ft. wind tunnel at the Ames Research Center of a complete configuration having an advanced technology wing design with high-lift devices and a powered engine/nacelle installation.

Propulsion System Technology

As with aircraft aerodynamics, the operating costs of small transport aircraft are also strongly dependent on the propulsion system characteristics. As illustrated in Figure 12, research could be conducted to investigate the application of advanced technology to engine components and propellers. In order to guide this possible research, advanced turboprop and turbofan engine design studies have been initiated with several engine manufacturers to determine those advanced technologies and design improvements that could result in reduced initial costs and improved energy efficiency, environmental compatibility, reliability, and maintainability. These engine studies are emphasizing the unique design characteristics of small transport sized (1000-5000 horsepower), severe duty cycle (high utilization), turbine engines. These include the increased sealing and cooling problems of small turbine blades, centrifugal compressor design, and the increased sensitivity to in-flight engine shut-down for twin engine aircraft. Engine component improvements such as laminated or dual property turbines, powdered metal and laser hardened gears, low emission combustors, net shaped powdered metal compressors, electronic engine controls, and on-condition engine monitoring systems will be investigated. Building on the ongoing advanced prop-fan technology research, propeller technology studies have also been initiated to examine the application of advanced technology to improve small transport propeller aerodynamic efficiency and reduce noise, weight, and maintenance. These propeller studies are also emphasizing the unique design characteristics of small transport sized propellers and the increased sensitivity to operating cost which allows the consideration of more expensive structural technology.

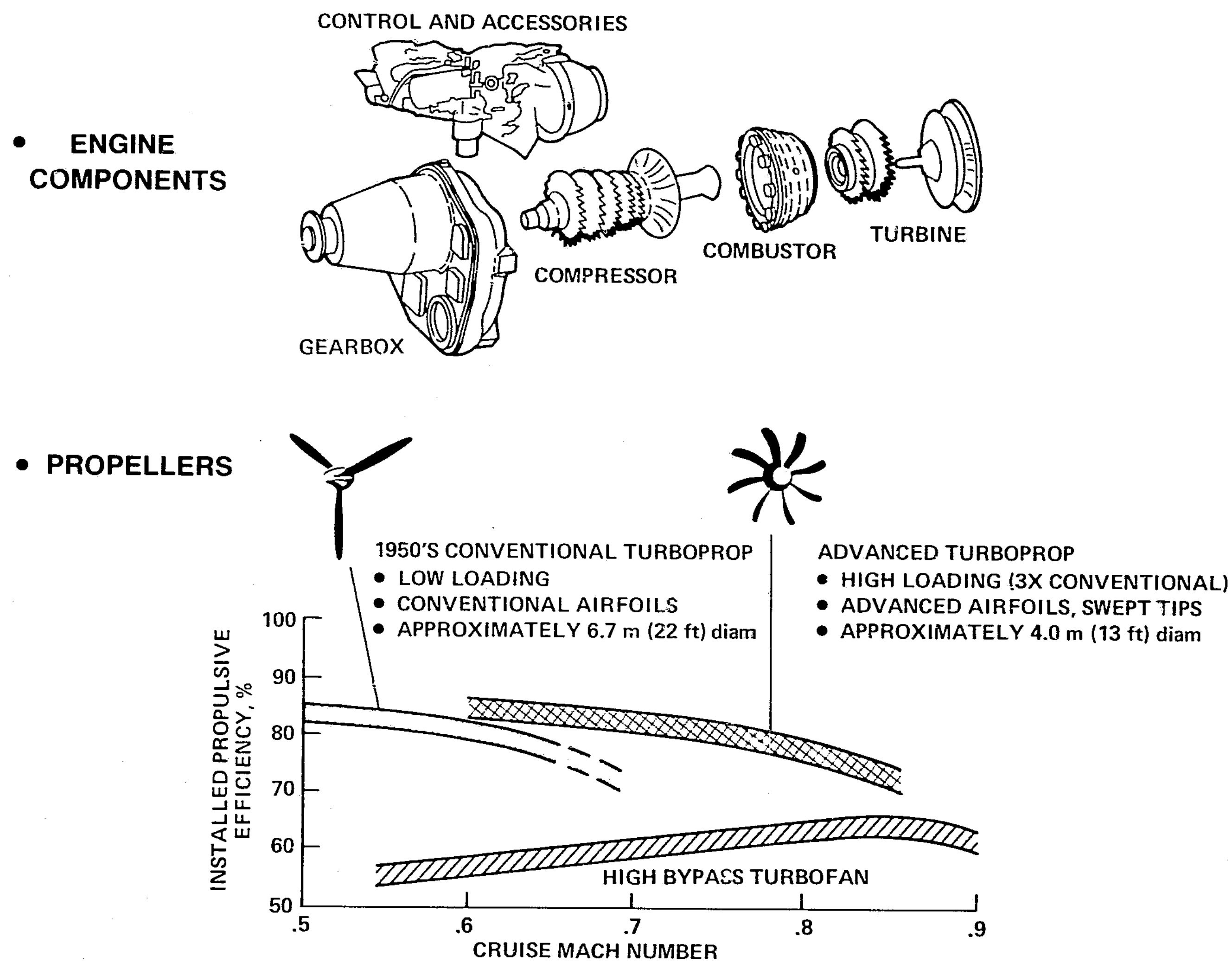

FIGURE 12. - PROPULSION SYSTEM TECHNOLOGY

The result of this propulsion system research could be improved design capability for advanced technology propellers and engine components for application to new small transport aircraft. This design capability could be verified through small-scale and full-scale wind tunnel testing of the most promising propeller designs and ground testing of selected engine components.

Aircraft Systems Technology

Future, small, short-haul transport aircraft should be provided with highly reliable, low-cost, advanced technology systems that improve safety of flight, terminal area compatibility, and handling and ride qualities while correspondingly lowering operational and maintenance costs. Small transport aircraft operate at lower altitudes and with lower wing loadings than large transport aircraft. As a result, the passenger ride quality is not as smooth and passenger comfort and anxiety are adversely affected. The potential of gust load alleviation systems technology to significantly improve the aircraft ride quality, reduce pilot workload, and reduce wing structural fatigue is under consideration. To date, developments in flight controls, avionics, and icing protection systems have primarily been directed at large commercial transport aircraft and general aviation aircraft with less emphasis on the needs of the small, short-haul transport aircraft. Furthermore, as a result of having to comply with expanded, more stringent air traffic controls brought about by large increases in both air traffic and terminal area congestion at many of the nation's large airports, the on-board flight control and avionics systems requirements have become increasingly more complex and costly. As illustrated in Figure 13, research could be conducted to evaluate the potential benefits of advanced flight control and avionics systems for enhanced safety of flight and terminal area operations, and to develop low cost, more effective icing protection systems having reduced power requirements.

Included could be an evaluation of the potential utilization for future new aircraft designs of such advanced technologies as fly-by-wire or fibre optics for control signal transmission, electrically powered control actuators, and integrated electric-hydraulic actuator units. Ground and flight tests could be conducted to develop and demonstrate the technology readiness of advanced flight control components and systems, and to determine the redundancy requirements applicable to establishing certification criteria. This testing could include breadboard set-ups to determine control system functional feasibility, component and system ground tests, and simulation with advanced control systems.

Avionics technology research could consist of evaluations of on-going avionics research in the areas of short-field, terminal area, guidance and navigation and in general aviation. In-house and contracted studies could also be performed to define avionics and avionic display requirements for new, advanced technology, small, short-haul transport aircraft. Advanced technology avionics concepts having possible application to these aircraft include digitized total-function avionics that integrate all of the necessary flight functions, such as navigation, guidance, control, and power management, and on-board minicomputer systems for assimilation and display of area navigation and flight information designed to enhance flight safety and reduce pilot workload. Testing could

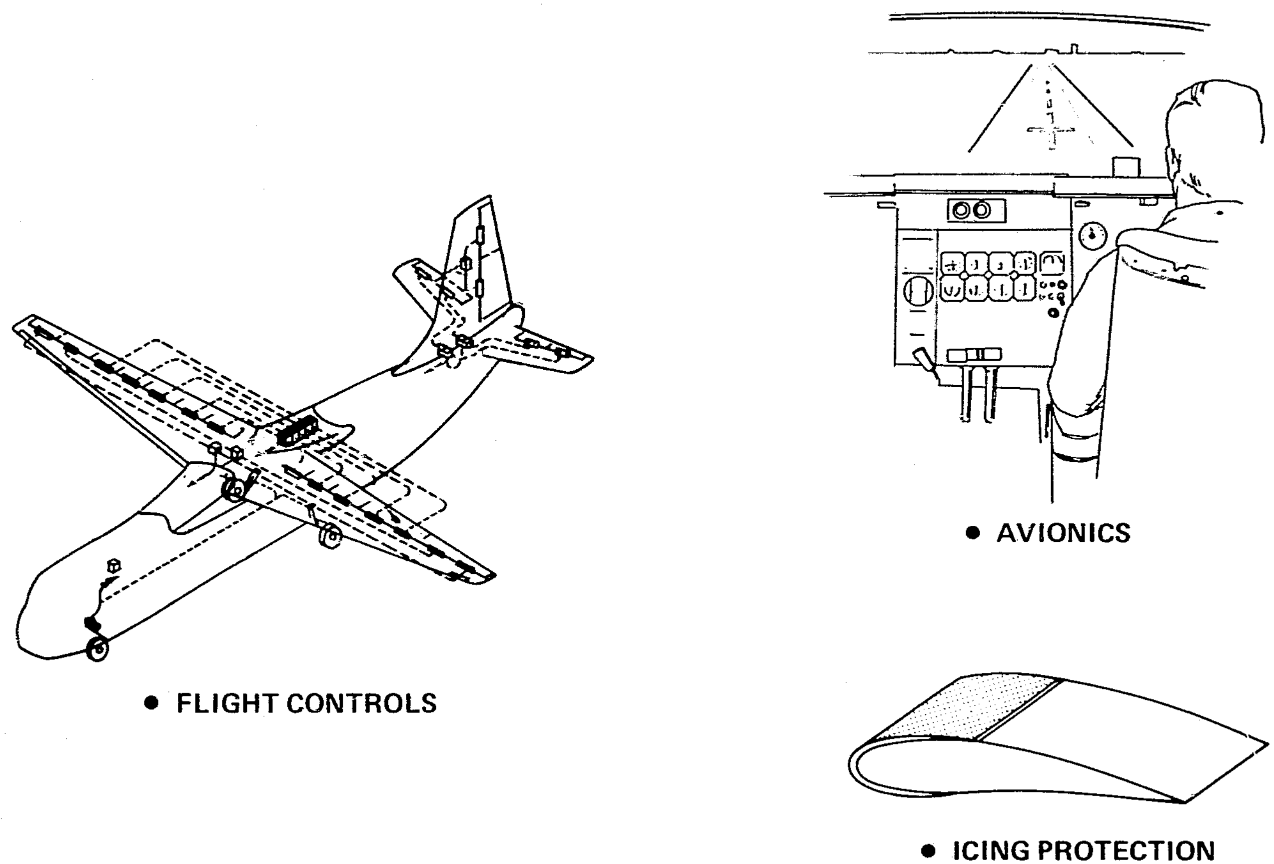

FIGURE 13. - AIRCRAFT SYSTEMS TECHNOLOGY

consist of breadboard functional tests, ground tests, and simulation of advanced avionics and avionic displays coupled with low-cost ground based navigation support systems.

Icing protection technology could be developed to improve the analytical methodology for predicting icing phenomenon, such as ice formation, airflow changes, and aerodynamic performance degradation due to ice accumulation. Included could be conceptual design studies of advanced icing protection systems, icing tunnel evaluations of advanced designs on individual and integrated aircraft components such as wings, propellers, and inlets, and selected flight test evaluations of advanced design icing protection systems. The icing protection methods that could be considered include improved leading-edge boots, vibration and impulse techniques, microwave heating, and icephobics (use of materials/substances that resist ice formation). Tradeoff analyses could be performed involving effectiveness, cost, power required, weight, complexity, reliability and maintainability. Criteria could be established for icing protection certification standards.

Structures Technology

A significant factor which can adversely affect the purchase and introduction into service of new, small, short-haul transport aircraft is the high acquisition cost of these aircraft. The acquistion cost, in 1978 dollars, of currently available, new short-haul, transport aircraft ranges from about $65,000 per seat (e.g., the 19 passenger Bandeirante EMB 110) to about $100,000 per seat (e.g., the 50 passenger de Havilland DHC-7). Potential structural research would emphasize the unique cost/weight tradeoffs associated with small transport aircraft. The structure must be rugged enough for the high airline type utilization and increased cycles more typical of larger transport aircraft, but cost considerations preclude scaling down large transport structural design techniques. Promising advanced composite or bonded structures technology could substantially reduce the number of parts and the resulting cost. A recent study by the Boeing Commercial Airplane Company (Reference 12) indicated that, based on a 200 airplane program, the utilization of advanced bonded aluminum honeycomb structures and manufacturing technology offers realistic potential for producing new, advanced technology, small, short-haul, transport aircraft with initial cost savings, from structures alone, of about $15,000 per seat. In addition, application of this technology offers the potential for appreciably increasing aircraft structural service life to a level matching or exceeding that of current commercial transport aircraft as well as reducing airframe maintenance costs. The structures technology is illustrated in Figure 14.

Studies are currently being conducted on the application of advanced aluminum alloys that offer the potential for improved corrosion resistance and strength characteristics. These alloys are the result of advanced metallurgical concepts, such as the addition of lithium to aluminum as an alloying element, and advances in powdered metallurgy manufacturing techniques that increase alloying element homogeneity and reduce material density. Investigations are also underway to assess the benefits and application potential of composites to small, short-haul, transport aircraft.

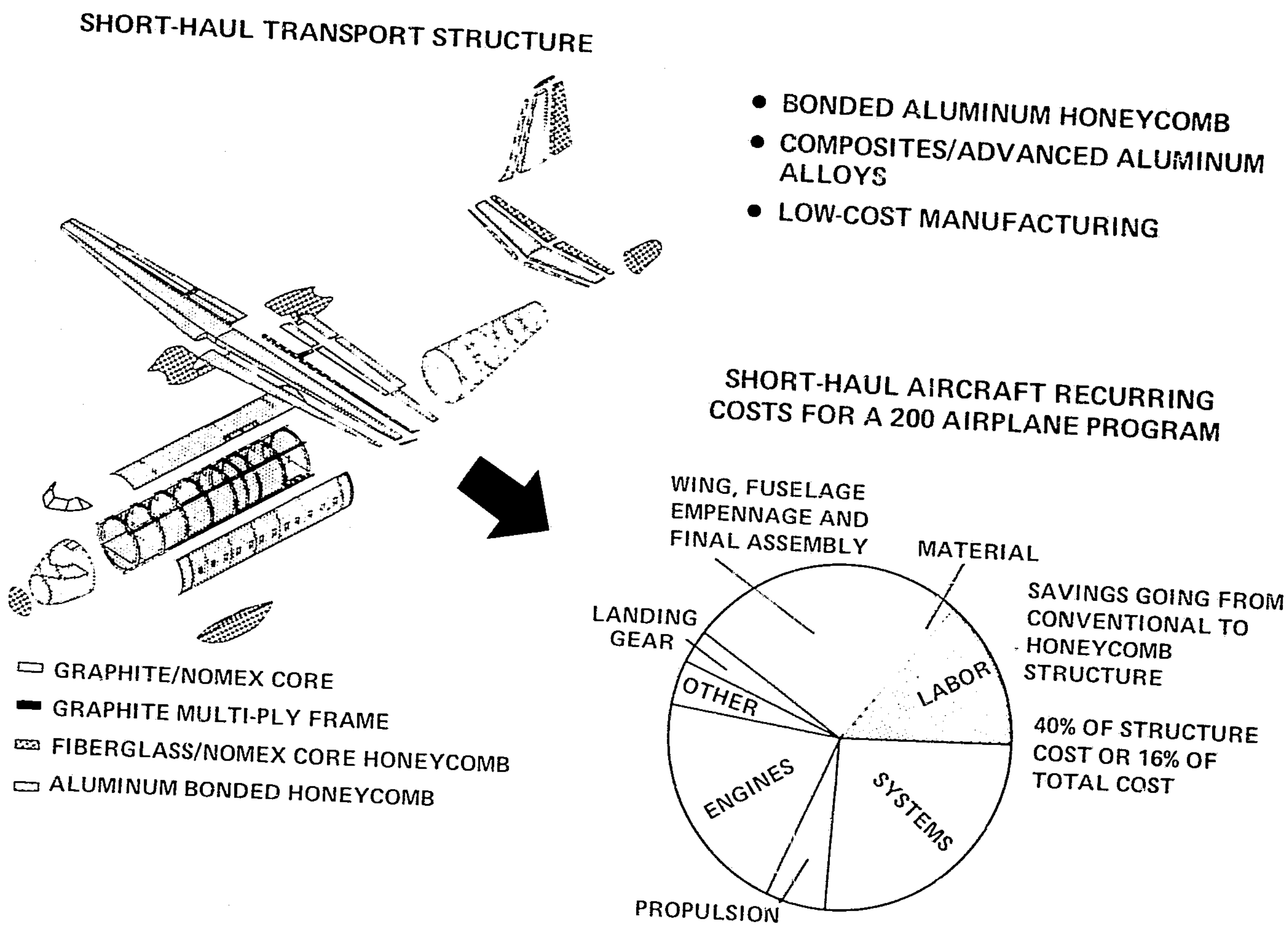

FIGURE 14. - STRUCTURES TECHNOLOGY

Flight type primary and secondary structural components incorporating advanced structures, material, and fabrication technology could be designed, built, and aerodynamically and structurally tested. The aerodynamic testing would be in conjunction with airfoil development on two-dimensional, large-scale models. Of particular interest would be the development and demonstration of techniques and methodology to establish and maintain airfoil contour during manufacture, and the ability to achieve and maintain surface smoothness with bonded structures for low drag and laminar flow enhancement. Ground-based structural and materials testing of large components could include demonstration and evaluation of corrosion resistance, strength, and fatigue properties and characteristics aimed at the development of certification criteria.

INTERIM CONCLUSIONS

Recently, many favorable social, economic, and regulatory changes have occurred which, coupled with increased passenger need for commuter air travel, have resulted in a strong demand for new, improved commuter aircraft and have significantly improved the opportunities for application of advanced technology to the design of these aircraft. The design of new small transport aircraft offers technology challenges and opportunities arising from the unique operational requirements resulting from their small passenger capacity, required high frequency of daily operations over short stage lengths in a low altitude environment, and necessity to operate from small community airports as well as from the major hub airports serving the certificated carriers. Based on discussions with aircraft manufacturers, airlines. and others, it appears that a need exists to clearly establish what an advanced technology data base can do for the design of improved small, short-haul transport aircraft specifically focused on the operational needs of the commuter airlines.

In response to this need, a Small Transport Aircraft Technology (STAT) research team has been formed within NASA and a broad range of advanced technology application studies have already been initiated with airframe, engine, and propeller manufacturers. These studies will assist in establishing the unique technology requirements for small transport aircraft, focusing the research into the most critical areas, and defining the research and development required to elevate the appropriate advanced technologies to the point that they could be applied to new small transport aircraft with confidence. In its planning, NASA is taking into consideration the fact that many of the potential technology needs for future small, short-haul transport aircraft may not be unique and may be satisfied by applying the results from other on-going or planned programs. For nearer-term potential applications, it appears that technology advancements in aerodynamics, propellers, and gust load alleviation could be made. Research opportunities in these three areas are being explored at the present time.

In this interim report, research opportunities are outlined in all the technical disciplines for potential long term application. However, the results of the recently initiated technology application studies will assist in focusing the research into the most critical and unique areas. The results of these studies and the initial research explorations already begun will be covered in the final report.

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APPENDIX

SMALL TRANSPORT AIRCRAFT TECHNOLOGY PERSONNEL

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SUMMARY OF

AIRLINE DEREGULATION ACT OF 1978

Policy Declaration. Policy statements include priority for safety, reliance on competitive market forces, the development of a regulatory environment responsive to public needs, the encouragement of air service at major urban areas through secondary or satellite airports, the prevention of predatory or anticompetitive practices, convenient small community service, and the encouragement of entry into markets by new carriers.

State Authority. A federal preemption provision precludes state regulation of any service performed as a result of CAB certification or exemption.

Route Applications. The CAB is directed to ensure that final decisions on route applications are made not later than 240 days after filing.

Dormant Authority. In dormant markets served by no more than one carrier, the CAB must grant a replacement authority to the first eligible carrier applying. In dormant markets where two or more carriers are operating, the Board must give authority to a willing carrier if the award of the route is not inconsistent with the public convenience and necessity.

Automatic Market Entry. The legislation allows automatic entry by a carrier on one route a year through 1981 with each carrier allowed to protect one route a year from such entry. All certificated carriers (scheduled, supplemental and intrastate) operating in excess of 100 million available seat-miles will be eligible for participation.

Issuance of Certificates. Although a carrier applying for a certificate is required to prove that he is fit, willing, and able to provide the proposed service, any opponent to the institution of such service has the burden of proof of showing that such service would be inconsistent with the public convenience and necessity.

Market Exit. A carrier must provide 90 days notice of any intent to terminate, suspend, or reduce service below that level which the board has determined to be "essential". Termination or suspension of nonstop or single-plane air service where only one carrier is certificated requires notice of at least 60 days before such proposed termination or suspension.

Mutual Aid Agreements. The existing Mutual Air Pact between airlines will be terminated. Any new pact must be approved by the CAB and ensure pact benefits will not cover more than 60% of actual operating expenses.

Labor Protection. If a carrier's work force under the regulatory reform provisions of this Act has been reduced more than 7.5%, an employee who becomes unemployed as a result of such a reduction may receive payments for up to six years based upon labor protection regulations that the Secretary of Labor must define within six months.

Commuter Air Carriers. Commuter exceptions to the more stringent economic regulation aspects of the Aviation Act will remain providing the commuter operator operates aircraft with a maximum passenger capacity of less than 56 or a cargo carrier operates aircraft with a maximum pay load capacity of less than 18,000 pounds. Such carriers must still conform with the current liability insurance requirements and other reasonable regulations that the Board shall adopt in the public interest. Under the Act, commuters will also be eligible for (1) subsidy when serving subsidy eligible points, (2) aircraft loan guarantees, and (3) participation in any joint fare program established by the CAB.

Small Community Air Service. The CAB will determine the minimum level of essential air service required by certain eligible communities, and will guarantee that level of service for a period of 10 years. Further, the Board is required to find a suitable carrier to replace a current carrier who suspends service to such communities and to cover the replacement carrier's losses for a period up to one year while it looks for yet another suitable replacement carrier. The current subsidy program (Class Rate VIII) will be continued for the next seven years. However, short-haul local service carriers may obtain subsidies under a new program based on community needs rather than on the carrier's needs. Also, after January 1, 1983 a subsidized local service carrier may be replaced on a route by a commuter or other short-haul local service carrier if such replacement will result in a reduction in or removal of subsidy and improved service.

Fares. Carriers will be allowed to increase fares 5% above the CAB established standard industry fare level without Board approval. They will be allowed to reduce fares up to 50% lower than this standard fare level without CAB approval, unless the Board determines that such fares would be predatory. The standard fare levels will be periodically revised to reflect inflation and changes in operating costs.

Sunset Provisions. The CAB's regulatory authority will be reduced over a period ending January 1, 1985, at which time the CAB will be abolished. The Board's domestic route program will be terminated at the end of 1981 and regualtory authority over fares and charters will expire on January 1, 1983. Regulation of the small community subsidy program will be transferred to the Department of Transportation with other selective functions transferred to the Department of State, Department of Justice and the U.S. Postal Service for matters dealing with foreign air transportation and the carriage of mail.

Loan Guarantee Program. The loan guarantee program will provide guarantees for loans up to $100 million for up to 15 years duration for equipment purchase. The Act extends eligibility for these loan guarantees to commuter and intrastate air carriers.